PETOIA

Ontario

Ministry of the Environment

STANDARDS DEVELOPMENT BRANCH OMOE
3693600004253

# Appendices

# Remote Sensing Techniques & Waste Management Assessments

## VOLUME II

**M.M. DILLON LIMITED**
*in association with*
*GARTNER LEE ASSOCIATES LIMITED*
*and*
*ONTARIO CENTRE FOR REMOTE SENSING*
*MINISTRY OF NATURAL RESOURCES*

**TD**
**159.3**
**.O6**
**R46**
**1982**
vol. 2
MOE

AIC : 39

TD
159.3
.O6
R46
1982
vol. 2

Remote sensing techniques &
waste management assessments /
76628

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

# REMOTE SENSING TECHNIQUES
# AND
# WASTE MANAGEMENT ASSESSMENT

## VOLUME II

VOLUME II

APPENDICES

APPENDIX A - COBOURG LANDFILL SITE
REMOTE SENSING STUDY RESULTS

APPENDIX B - WHITBY LANDFILL SITE
REMOTE SENSING STUDY RESULTS

APPENDIX C - OAKVILLE LANDFILL SITE
REMOTE SENSING STUDY RESULTS

APPENDIX D - BAYVIEW PARK LANDFILL SITE
REMOTE SENSING STUDY RESULTS

APPENDIX E - BURLINGTON LANDFILL SITE
REMOTE SENSING STUDY RESULTS

APPENDIX F - UPPER OTTAWA STREET LANDFILL SITE
REMOTE SENSING STUDY RESULTS

# Appendix A
# Cobourg site

## Remote Sensing Techniques & Waste Management Assessments

# 1. INTRODUCTION

The Cobourg landfill site is located about 7 km east of Cobourg, just south of Highway 401 (Figure A.1). It is one of six southern Ontario landfills used in the study "Remote Sensing Techniques and Waste Management Assessment", prepared for the Ontario Ministry of the Environment. The purpose of this study is to evaluate specific remote sensing techniques for application to landfill monitoring and identification.

Colour and colour infrared aerial photography, and thermography was acquired during 1980. This imagery, along with archival photography was interpreted for application in monitoring and identifying existing landfill sites. A summary of the results, comparative evaluation of techniques and final study conclusions are presented in Volume 1 of this report.

This appendix contains the detailed results for the Cobourg site only. The appendix is one of six similar appendices comprising Volume 2. Together they provide all the detailed observations and data accumulated during this study. Each appendix is designed to be used separately with Volume 1, (the general text) if desired.

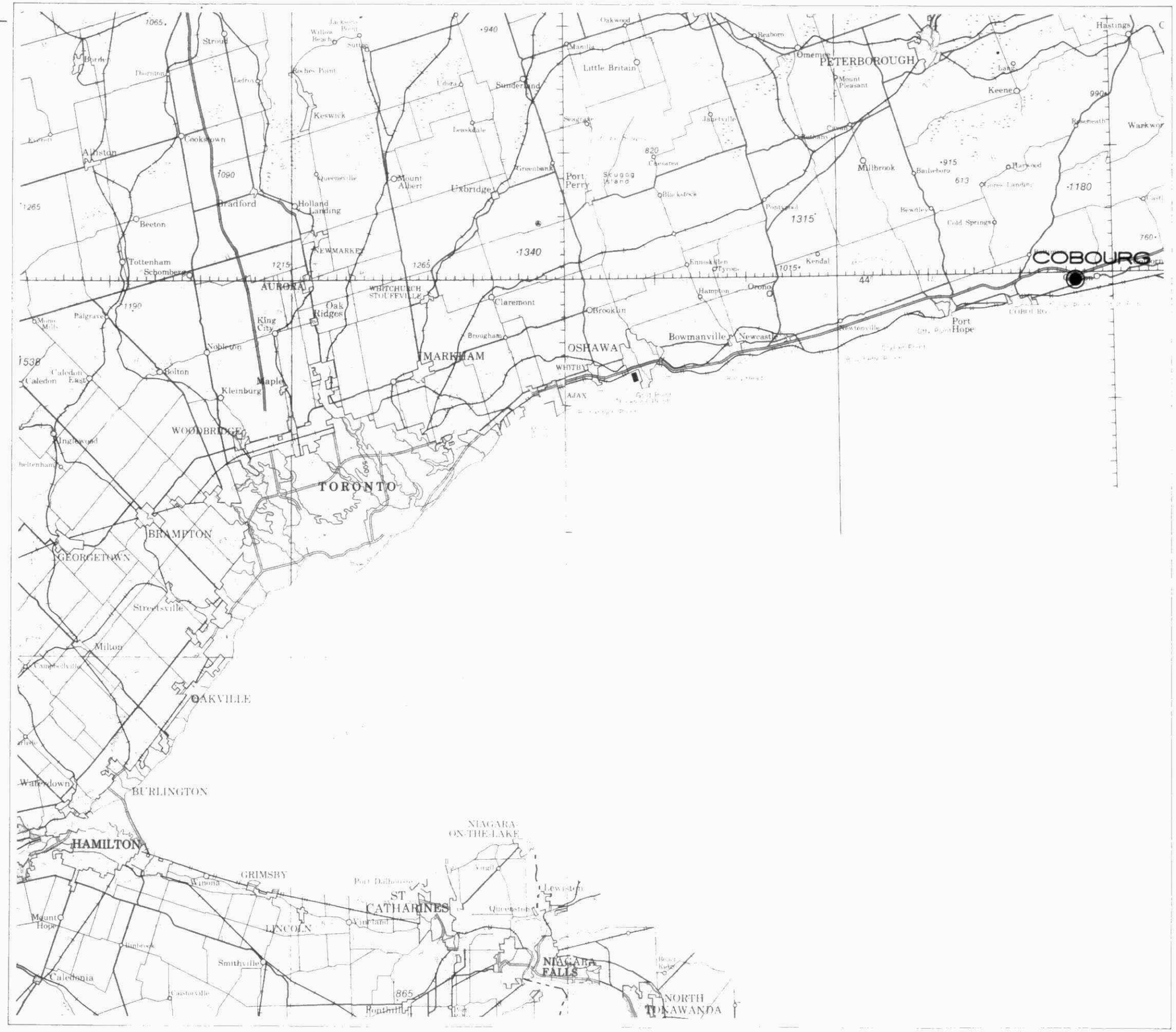
## 2. PHYSICAL SETTING

The Cobourg landfill occupies a stream valley in a drumlinized glacial till plain. The landfill has developed in two stages: i) the original landfill which infilled the valley covering the stream and south valley wall; and ii) the present workings developed in trench excavations into the silty sand till on the north valley wall.

Shallow glaciolacustrine sands and gravels overlie the silty sand till on the valley walls and floor (Figure A.2). Most of the sands beneath the original landfill site have been removed by extraction operations which have since extended into the eastern part of the property. Previous investigations indicate the refuse is placed directly on the silty sand till.

A creek - that originates north east of Highway 401 - flows beneath the landfill in a culvert. The drainage divide separating this creek from the watershed to the south is shown on Figure A.2. This divide also approximates the ground water divide which hydrogeologically contains the possible impacts of the landfill to the environment of the site creek.

A detailed hydrogeological study of the original landfill site was undertaken in 1974. The cross sectional sketch below outlines the general ground water flow pattern identified.




Ministry of the Environment
Ontario

# A·1 Location map

● SITE LOCATION (ACTIVE)

0 10 km

## Remote Sensing Techniques & Waste Management Assessment


M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Ministry of the Environment
Ontario

# A·2 Physical setting

LANDFILL AREA (NOVEMBER, 1980)

TILL

SAND & GRAVEL

WETLAND

PITS AND DISTURBED LANDS

STREAM

DRAINAGE DIVIDE

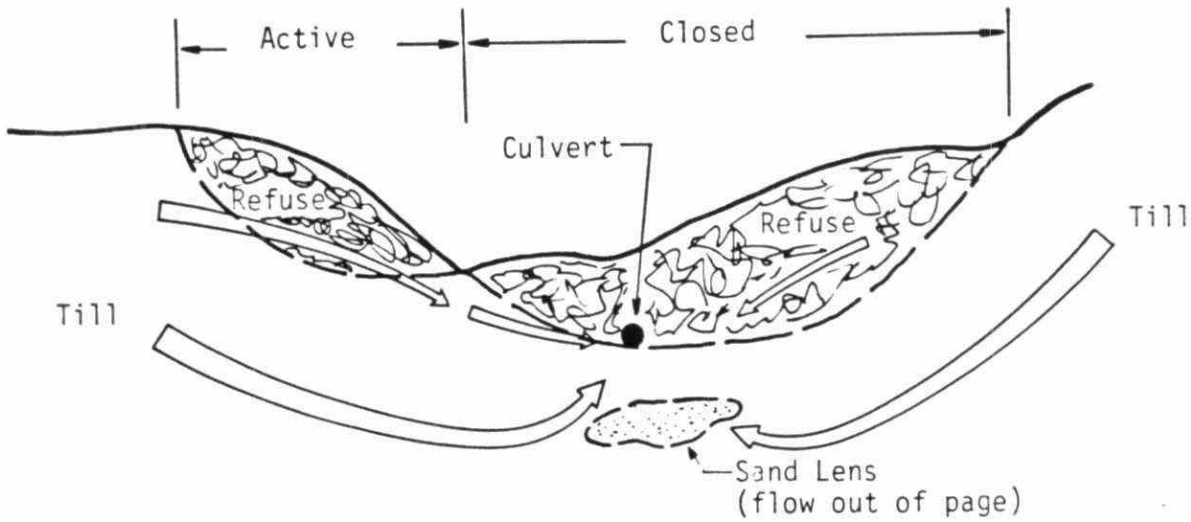
0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Schematic Cross Section of Cobourg Landfill

NORTH SOUTH




A very local recharge - discharge system has developed within the garbage. Precipitation and surface runoff infiltrates through the garbage and, prior to remedial measures seeped out of the flanks of the garbage and into the creek. However, a leachate collection system was installed (Figure A.3) and leachate is now collected and pumped to the top of the landfill where it is allowed to recirculate through leaching trenches.

Another, more regional ground water flow system is associated with the valley environment. Here, ground water recharges the topographic highs on either side of the creek valley and flows towards the creek, where it discharges.

During the hydrogeological study, borings also identified an east-west trending sand lens in the till beneath the refuse. Water quality testing of ground water from the lens identified heavy iron contamination, not from the landfill, but from wire wastes buried in trenches upstream of the site. Contaminated ground water appears to discharge about 200 m downstream, in a wooded area. Except for heavy iron precipitation no environmental impacts were observed in 1980.

## 2.1 Site History

The history of operations for the Cobourg site is based primarily on notes available from Ministry of the Environment files. Records for the period prior to 1970 are not readily available, therefore the following descriptions are derived from recorded accounts of site operations and development.

In continuous operation since 1957, the Cobourg landfill site is privately owned and operated by J.C. Engleson and Sons under contract with the Town of Cobourg. Landfilling is carried out by bulldozer in former gravel pits.

A creek crosses the site, and to allow for the planned landfilling of wastes over the creek, a storm sewer was installed to carry creek flows.

By 1969 landfilling had been carried out on both sides of the creek and leachate infiltration via storm sewer joints suspected since an orange discolourization of the creek was noted. The 1969 records note that ground water was present in site excavation. In 1971 sewer joints were sealed to prevent leachate leakage to the creek.

Ministry of the Environment
Ontario

Keating Site

# A-3 Site plan

PROPERTY BOUNDARY

LANDFILL LIMITS

CURRENT OPERATIONS

LEACHATE COLLECTION SYSTEM

PERFORATED COLLECTION LATERALS

LEACHATE TRANSMISSION SEWER

FORCEMAIN

P.S. PUMPING STATION

DISPERSAL DITCH

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Burning of wastes become an operational practise and was carried out primarily to reduce the bulk of bush and other wood wastes.

In 1973 evidence of ground water detention was noted but was generally limited to the landfill site area. A study was commissioned to investigate the problem and to recommend the type and extent of control works required.

In 1975, as a result of the study undertaken to investigate site leachate discharge, a leachate collection system was installed. This is comprised of a perforated toe drain collection pipe at the base of the site, a leachate pumping station, a forcemain and a leachate recharge trench. Leachate collected by the system at the base of the site is recharged to completed areas of the site, and thus to the site refuse via the recharge trench. The present area used for landfilling is estimated at 7.3 hectares.

The estimated rate of landfilling in 1971 was 63 tonnes/day serving a population of 12,000 and utilizing a site area of 4.1 hectares. The present area used for landfilling is estimated at 7.3 hectares.

## 3.0 METHODOLOGY

The prime objective of the study was to evaluate remote sensing techniques for thier applicability to waste management programs. Six sites were selected for the study and a program for acquisition of remote sensing data for the sites was developed.

Four remote sensing devices were selected for the study:

i) colour aerial photography
ii) colour infrared aerial photography
iii) aerial thermography
iv) archival photography

Each sensor was expected to be capable of providing specific data on the condition of each site - in particular the discharge of leachate (colour aerial photography and aerial thermography). The sites selected represented a range of differing hydrogeological conditions, with a known history of surface discharge of leachate, and with various stages of site operation and site rehabilitation.

The selected sites were:

Cobourg Landfill Site
Whitby Landfill Site
Oakville Landfill Site
Bayview Park Landfill Site (in Burlington)
Burlington Landfill Site
Upper Ottawa Street Landfill Site -
(in Hamilton)

The program for evaluation of sensors comprised initially the acquisition and review of hydrogeological assessments made

for the site through previous studies. In addition, to assist in providing an understanding of site history and past operations, archival photography was obtained dating back to pre-landfill period and taken at intervals ranging from 5 to 7 years to most recent photography available. To further assist in constructing a site development history, a review of Ministry files for the site was made. Observations of site operations and leachate discharge were reported and give insight on the development of leachate mounding and on operational procedures which have conributed to present site conditions.

The schedule for remote sensing data acquisition was:

| Sensor | Flight Date | Field Reconnaissance |
|---|---|---|
| colour photography | 12 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 30 April 1980<br>August 1980<br>19 November 1980 |
| colour infrared photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 30 April 1980<br>August 1980<br>19 November 1980 |
| thermography | 17 April 1980<br>26 November 1980 | 30 April 1980<br>August 1980<br>19 November 1980 |

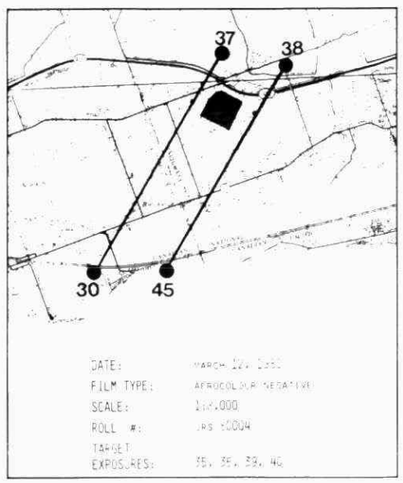
Photography scale was changed from 1:8000 for March and April flights to 1:6000 for July and November flights. Average flying altitude for thermography was 1050 m, giving an approximate scale of 1:14000. Data acquisition details are given on Figure A-4.

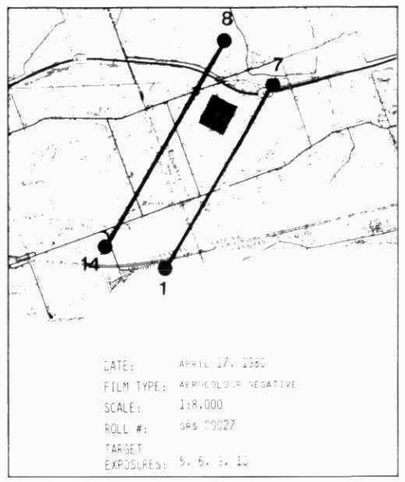
After each flight, photography and imagery were examined and preliminary interpretations made. Detailed field reconnaissance was made to confirm interpretations and to identify features undetected on the sensor data. Photography and imagery for each flight were annotated and annotations for subsequent flights compared so that assessment of the relative effectiveness of sensors under varying seasonal conditions would be made.

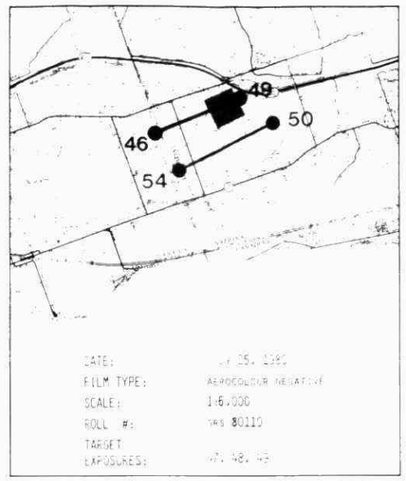
Following completion of all data acquisition, interpretations and field work, comparative assessments of data with respect to season, sensor type, and type and extent of features sensed were made. Site features detectable in the field were noted and compared to those interpreted from photography and imagery. These records and interpretations were used as a basis for determining the effectiveness of each technique.

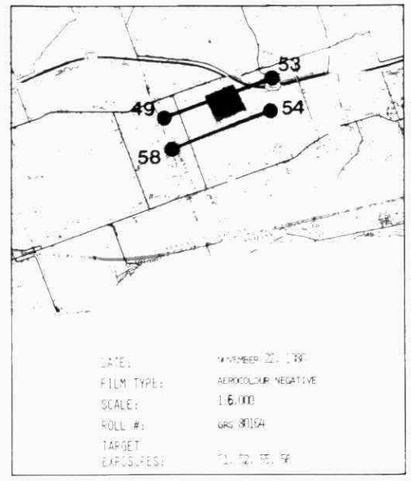
The relative merits of the various sensors in satisfying the study objective and taking into account relative costs of data acquisition were then assessed.

TRUE COLOUR

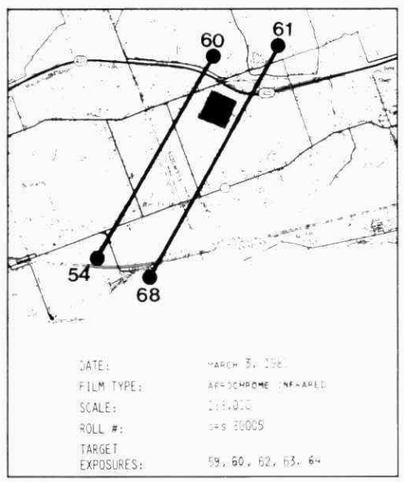


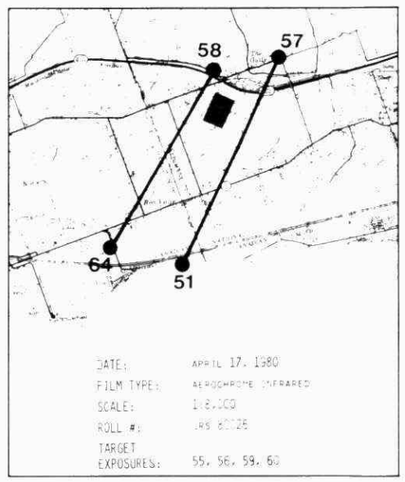



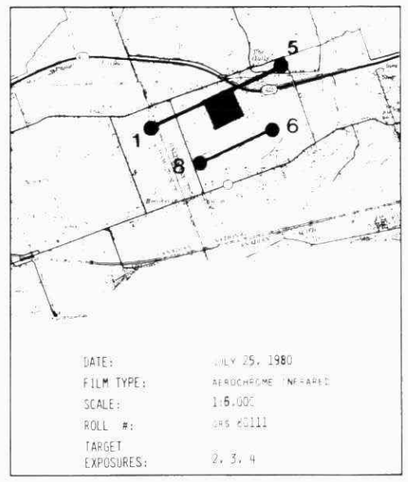



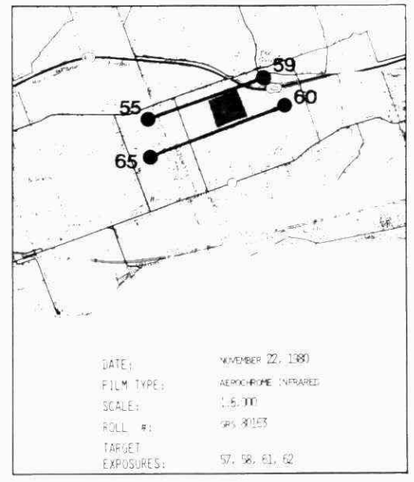




COLOUR INFRARED

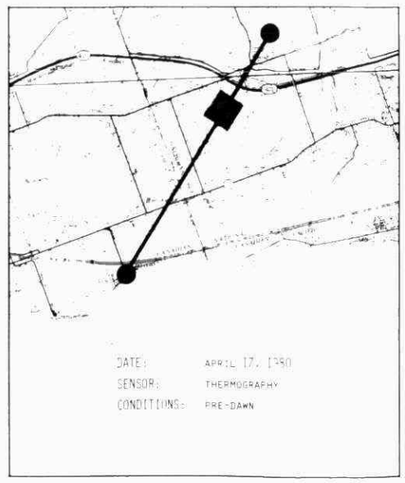


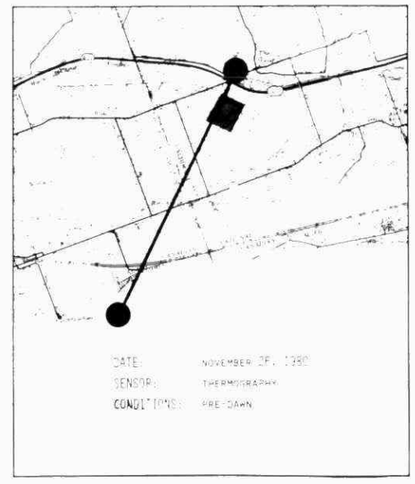




THERMOGRAPHY




LATE WINTER | SPRING | SUMMER | AUTUMN

Ministry of the Environment
Ontario

# Cobourg site

## A·4 Data Acquisition (1980)

0 2 kilometres

## Remote Sensing Techniques & Waste Management Assessment

**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

# 4. STUDY RESULTS

## 4.1 Archival Photography

The existing black and white photography shows the development of the Cobourg site from a small gravel pit just south of the stream (1954) to a landfill disposal area spanning the stream valley (1978). The sequence of landfilling and the gravel pit extension are shown on Figure A.5. Significant details observed in the various years are outlined below.

Original surface topography is visible on the 1954 imagery. A small gravel pit is located south of the stream. By 1959, the pit has expanded to cover about two-thirds of the future landfill site. There does not appear to be any refuse in the site at this time. The development of the first landfill area is visible on the 1965 and 1971 photography. By 1965, landfilling in the former gravel pit has extended to the south bank of the stream. Continued refuse disposal enlarges the height and area of the landfill mound and by 1971, the refuse mound fills the lower part of the original valley, and has covered the stream.

The land surface appears to be disturbed just north of the stream on the 1965 and 1971 photography. However it is not clear whether this relates to some landfilling activity or simply to construction activity in diverting the stream into the culvert beneath the refuse.

By 1978, the original refuse mound is closed, and the leachate recharge trench is installed. Landfilling is now occurring in trench excavations on the north valley slope. This activity is creating a slight mound and recontouring of the original slope. Landfilling is also occurring south of the stream, and east of the closed site. The area of sand

and gravel extraction does not appear to have increased since 1971.

Two other features are noted on the 1978 photographs: i) overflow from the recharge trench; and ii) development of vegetation gaps in tree cover downstream of site. These gaps have developed since 1971 and may indicate vegetation damage due to leachate seepage from the closed landfill.

## 4.2 Late Winter Data - 1980

### 4.2.1 Sensing Conditions

The March 12, 1980 photography was obtained at 1:8000 scale. A light snow cover blanketed most surfaces, but this snow had melted on some west and south-facing slopes and drifted off some fields. Weather data prior to March 12, 1980 are listed in Figure A.6.

### 4.2.2 Diagnostic Features

a) Colour

Darker soil tones (wetness) at two locations may indicate leachate seepage or snow melt runoff. No staining or snow gaps were detected.

Observations below are located on Figure A.7.

Station 1: Darker soil area on west face of closed landfill could be seepage or shadow.

Ministry of the Environment
Ontario

# A·2 Physical setting

LANDFILL AREA (NOVEMBER, 980)

TILL

SAND & GRAVEL

WETLAND

PITS AND DISTURBED LANDS

STREAM

DRAINAGE DIVIDE

0 500 metres

## Remote Sensing Techniques & Waste Management Assessment

**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

FIGURE A.6

WEATHER DATA[1]: COBOURG LANDFILL

| DATE | TEMPERATURE (°C) | | | Precipitation[2] |
|---|---|---|---|---|
| | Maximum | Minimum | Mean | |
| **Late Winter** | | | | |
| March 7 | 0.0 | - 4.5 | - 2.0 | |
| 8 | .5 | - 2.0 | - 1.0 | 10.0 (S) |
| 9 | .5 | - 6.0 | - 3.0 | Tr (S) |
| 10 | 4.5 | - 1.0 | 2.0 | 2.0 (R) |
| 11 | - 3.0 | - 6.0 | - 4.5 | |
| 12 | - 6.0 | -14.0 | -10.0 | |
| **Spring** | | | | |
| April 12 | 7.0 | 3.5 | 6.0 | 11.2 (R) |
| 13 | 7.0 | 3.0 | 5.0 | |
| 14 | 7.0 | 0.0 | 3.5 | |
| 15 | 7.5 | 3.0 | 5.0 | .4 (R) |
| 16 | 3.5 | - 4.5 | - .5 | |
| 17 | 7.0 | - 5.5 | 1.0 | |
| **Summer** | | | | |
| July 20 | 26.5 | 17.0 | 22.0 | 7.4 (R) |
| 21 | 28.0 | 18.0 | 23.0 | 2.0 (R) |
| 22 | 21.0 | 18.0 | 19.5 | |
| 23 | 25.5 | 16.0 | 21.0 | |
| 24 | 23.0 | 15.5 | 20.0 | |
| 25 | 24.0 | 17.5 | 21.0 | |
| **Autumn** | | | | |
| November 16 | - .5 | - 7.0 | - 4.0 | |
| 17 | 0 | - 8.0 | - 4.0 | 2.0 (S) |
| 18 | 3.0 | - 4.5 | - 1.0 | |
| 19 | 4.0 | - 6.5 | - 1.0 | |
| 20 | 6.0 | - 4.0 | 1.0 | |
| 21 | 5.0 | 3.0 | 4.0 | |
| 22 | 5.0 | 2.0 | 3.5 | |
| 23 | 8.0 | - 2.5 | 3.0 | 1.0 (R) |
| 24 | 8.0 | 4.0 | 6.0 | 2.5 (R) |
| 25 | 1.0 | - 4.0 | - 1.5 | Tr (R) Tr (S) |
| 26 | 5.0 | - 6.0 | - .5 | |
| 27 | 4.0 | - 4.0 | 0.0 | 5 (R) 2 (S) |

1. Source: Cobourg Weather Station
2. (R) rain in mm
   (S) snow in cm
   Tr trace of precipitation

Station 2: Darker soil area across access road could be seepage.

b) Colour Infrared

Darker soil tones (wetness) along the access road may indicate leachate staining or snowmelt runoff. No gaps or snow staining are visible.

Observations below are located on Figure A.7.

Stations 2, 3: Dark soil tone on road due to seepage or snowmelt.

Station 4: Seepage (dark tone) related to active face.

c) Thermography

Thermography obtained during daylight hours of March 28 1980 was not suitable for analysis.

## 4.3 Spring Data

### 4.3.1 Sensing Conditions

The April 17, 1980 photography exhibits typical spring conditions: leaf-free deciduous trees, snow-free ground surface and high water table conditions. While good for photographic interpretation these conditions are less suitable for thermography. The lower temperature contrasts make the thermal imagery increase background thermal infor-

Ministry of the Environment
Ontario

Solinge Site

# A·7 Late winter data
## (March 1980)

●4 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80004-36
COLOUR INFRARED PRINT
– GRS80005-63

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

mation. Weather data preceding April 17, 1980 are listed in Figure A.6.

4.3.2 Diagnostic Features

a) Colour

Red-brown leachate staining caused by overflow of the recharge trench is detected on the colour prints. In addition, leachate is seeping from the base of the slope east of the active landfill.

Observations below are located on Figure A.8.

Station 5: Zone of leachate seepage at base of slope approximately 30 m north of stream and 20 m long; shows characteristic reddish leachate staining against greenish-brown grass cover; lighter "streams" visible.

Station 6: Reddish-brown surface water ponding at base of active face; "fresh" leachate from uncovered active landfilling trench.

Station 7: Non-vegetated, shallow "gully" on grassed cover, east side of expansion landfill area; possible intermittent leachate seepage.

Station 8: Reddish-brown leachate staining against grass cover as a result of spill from leachate recharge trench; flows over the southwest slope of closed fill area.

Station 9: As in 8; with flow to east.

b) Colour Infrared

Leachate staining is less distinct on the colour infrared than on the colour prints, appearing as a dark greenish- blue tone against a blue toned background. The leachate "streams" are a light blue colour.

Observations below are located on Figure A.8.

Station 5: Light blue "streams" (sediment laden) visible seeping from toe of slope; possible leachate discharge.

Stations 6, 8, 9: Dark greenish-blue tone visible on grass; suggests soil wetness or leachate seepage; associated with active face and recharge trench.

c) Thermography

The April imagery was level sliced to enhance thermal anomalies. Several discharge points (bright anomalies) are located around the site. However, there is no feature to distinguish between leachate and natural ground water discharge.

Observations below are located on Figure A.8.

Stations 8, 9: The warm leachate in the recharge trench produces a bright elongated thermal anomaly (similar to Station 10).

Station 10: Bright, elongated anomaly identifies spring flow or discharge. Since this "spring" is well upstream of the site it is probably ground water seepage.

Ministry of the Environment
Ontario

Tobourg site

# A·8 Spring data
(April 1980)

●18 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80027-9
COLOUR INFRARED PRINT
– GRS80026-59

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Stations 14, 15: Discrete thermal anomaly, much warmer (brighter) that the surroundings occur at both stations. Both are masked by vegetation, decreasing thermal contrast. Since downstream of site, this could be contaminated seepage.

Station 17: A very bright (hot) anomaly with considerable thermal influence.

Station 18: Relatively warm thermal anomaly with extensive area probably identifies ponded water in gravel pit.

d) Field Observations

Field visit on April 30, 1980 identified several leachate and natural ground water springs. Leachate contaminated discharge occurred within 100 m of the site; natural springs occurred along the stream valley, farther away from the site.

Observations below are located on Figure A.8.

Station 5: Heavily iron stained, scummy seepage occurring near base of slope in field east of landfill; extends about 30 m; characteristic leachate appearance; conductivity 3500 $\pm$ umhos.

Station 6: Small leachate seep, exiting halfway down "new" landfill slope, into ditch along access road.

Stations 8, 9: Leachate collection system - leachate collected is pumped into recharge trench; leachate flowed overland from both west and east ends of trench during spring.

Station 10: Spring from blocked culvert under Highway 401.

Station 11: Natural iron staining, scum on some surface waters (springs, wetland pools).

Conductivity: i) small pool; 800 ± us, isolated pool; surrounded by clear pools.

ii) adjacent spring discharge 700 ± us.

Station 12: Heavily coloured leachate spring entering stream from north stream bank; immediately upstream from culvert inlet.

Station 13: Leachate spring on west face of site, beside tree trunk.

Station 14: Spring in south stream bank, just above stream level, about 30 m downstream from site; leachate contaminated.

Station 15: Spring with iron staining; about 120 m downstream of site; no odour.

Station 16: Burning area - burned materials buried back to original hill; green "leachate" from toe of old burning face; currently burning materials.

## 4.4 Summer Data - 1980

### 4.4.1 Sensing Conditions

The full vegetation cover conditions on the July 25, 1980 photography provided the only opportunity to examine vegetation stress on the colour infrared film. Some natural vegetation stress, due to summer drought, is visible in crops and grass cover on the landfill. Tree cover and ground cover in lower areas show vigorous growth. Weather data prior to acquisition are listed in Figure A.6.

New berms have been constructed around the recharge trench to prevent future leachate overflow. Several parallel trenches have been dug in the glacial till, on top of the hill south of the landfill, in preparation for sewage sludge disposal.

### 4.4.2 Diagnostic Features

a) Colour

Light reddish-brown staining identifies leachate staining of grass at the recharge trench and the seepage area observed on photographs in the spring. However, this tone is not a unique indicator of leachate - similar tones occur further downstream.

Vegetation gaps - areas of dead trees with green, apparently healthy ground cover - occur downstream of the landfill. These may be related to leachate seepages. However, magnification of one gap (Station 23) indicates the area is logged; the brown ground tone is similar to leachate but does not appear to be leachate staining when examined stereo-

scopically. Natural vegetation gaps occur in an adjacent watershed (Station 31).

Observations below are located in Figure A.9.

Station 19: Stream lacks vegetation for about 20 m downstream of site.

Station 20: Partial vegetation kill for about 30 m downstream of site on south side of stream grey brown (dead) trees in cattails.

Stream 21: Reddish-brown staining against brown grass at leachate overflow from west end of recharge trench; note vigorous grass halo around stain.

Station 22: Several dead (grey) trees are visible in partial clearing.

Station 23: Large clearing with reddish-brown tone along the stream side of the clearing; appears to be cut area, although tone is similar to leachate staining at this site.

Station 25: Reddish-brown staining due to overflow from recharge trench along east side of soil cover pile.

Station 29: Reddish-brown staining at base of slope; remnant of larger leachate seep in the spring; tone is just slightly more reddish than some of stressed grass areas.

Station 31: Natural vegetation gap.

Ministry of the Environment
Ontario

Cobourg site

# A·9 Summer data

( July 1980 )

●31 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:6000)
COLOUR PRINT – GRS80110-47
COLOUR INFRARED PRINT – GRS8011 3

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

b) Colour Infrared

Red-brown staining is more distinct on the colour infrared than on the colour. The yellow-green tone (note change from greenish-blue in spring) contrasts sharply with the background. However, this is not a unique tone - the same tone occurs at an apparent cut area downstream.

Dead trees and areas of lightly stressed (orange-red tone) ground cover are visible downstream of the site. These areas - especially the closest - may be related to the landfill, but there is no conclusive photographic evidence.

Positive vegetation stress (healthy vegetation) on the landfill also identifies possible leachate seepage. The best example is the halo of green grass visible around the leachate spill from the recharge trench.

Observations below are located on Figure A.9.

Station 19A: Along banks downstream from site and south along fence line about 30 m, vegetation appears lightly stressed (orangey tone); at west end of area, dead trees (grey tone).

Station 21: Leachate staining appears as distinctive yellow-green stain on grass; note halo of "red" or active vegetation growth around spill due to greater soil moisture.

Station 22: Stressed (grey) vegetation visible in clearing.

Station 23: The brown tone is visible on the colour infrared in this clearing as the same yellowish-green tone as leachate.

Station 24: Individual stressed trees around landfill.

Station 25: Leachate stain appears as yellowish-green stain on grass.

Station 26: Area of vigorous (red) grass corresponds to earlier leachate spill area.

Station 27: Small patches of vigorous (red) grass cover adjacent to surface gullies on landfill may indicate local seepage.

Station 28: Clump of small trees along north bank of stream, downstream from leachate seep, appears stressed (pink tone).

Station 29: Leachate stain appears as yellowish-green stain on grass; more distinctive than tone on colour photography.

Station 30: Soil wetness (dark soil tones) around site may indicate leachate seepage.

Station 31: Stressed trees (grey) in wooded wetland; not landfill related due to geological position, stress due to unknown cause.

c) Thermography

Thermographic coverage of the Cobourg landfill is unavailable due to the emergency use of the thermal line-scanner for forest fire mapping. However, the thermographic investigation of leachate outbreaks is considered to be least effective during summer.

d) Field Observations

Observations during the July field visit confirmed leachate seepage and landfill conditions observed in April. Several very small leachate seeps were identified along the access road at the landfill toe. These are not visible on the summer imagery.

## 4.5 Autumn Data - 1980

### 4.5.1 Sensing Conditions

The November 1980 imagery was obtained under typical late autumn conditions. Deciduous trees are leaf-free and snow that covered the ground during the 19 November 1980 field visit has melted. Weather conditions prior to 26 November 1980 are listed in Figure A.6.

Conditions are excellent for thermography at this season. The cold nighttime temperatures and low soil moisture provide a thermally flat background for easier detection of leachate springs. Unfortunately, "noise" is visible in some places on the imagery. This is due to mechanical problem in taping the data during acquisition and is impossible to correct.

### 4.5.2 Diagnostic Features

a) Colour and Colour Infrared

The former leachate overflow area is visible on the colour and the colour infrared film as persistent grass growth. No other leachate indicators are visible.

Observations below are located on Figure A.10.

Colour

Station 34: Green tone in brown toned dead grass corresponds to leachate overflow zone. Leachate trench has been bermed to reduce overflow.

Station 32: Along river bank, downstream of site no indication of leachate. Light brown tone represents dead cattails (natural winter die back).

Colour Infrared

Station 34: Light pink tone corresponds to green ground cover in area of leachate overflow zone.

Stations 32, 33: Light green tone is natural winter die back of vegetation (false colour of light brown tone).

c) Thermography

Several bright distinct anomalies are detected on the analog thermal imagery. Although having a signature indicating discharge, they detected ground water seepage, the recharge trench and fire at the burn site. No actual leachate seepage was detected. Warm anomalies identify surface ponding.

The observatons below are located on Figure A.10.

Station 34: Very bright (hot) distinct anomaly located at west end of recharge trench; ice-free area on ponded leachate.

Ministry of the Environment
Ontario

Coburg site

# A·10 Autumn data

( Nov. 1980 )

●44 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:6000)
COLOUR PRINT
– GRS80164-52
COLOUR INFRARED PRINT
– GRS80163-58

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Stations 36, 45: Very bright (hot) distinct thermal anomaly located downstream and upstream respectively of site; Station 45 is ground water discharge; Station 36 is possible discharge from iron contaminated sand lens in till.

Station 41: Extremely hot (bright) zone on thermography locates the fire at the landfill burn area.

Station 43: Warm thermal anomaly at former leachate seep.

Stations 44, 46: Warm thermal anomalies (less distinct and bright than at Stations 34, 36, 41 and 45) suggest probable surface ponding.

d) Field Observations

The 19 November 1980 field visit concentrated on checking leachate discharge along the valley downstream of the site. A zone of small, active leachate seeps was melting the thin snow cover on the south side of the stream, for about 60 to 80 m. A few small leachate seeps were also detected in the stream bank and at the landfill toe. the vigorous leachate seepage occurring just north of the site in spring has ceased. Overflow from the leachate trench had also ceased, and there was no evidence of staining on the ground surface.

The observations below are located on Figure A.10.

Station 32: Leachate seeps are occurring along the south stream bank, between the tree edge and stream. Seepage extends about 60 to 80 m downstream. Cattails show good summer growth with small dead cedar and pine trees. Leachate-reddish-black colour, locally melting snow; temperature of

seeps is 6.5 to 7.5°C; ground water seepage in the treed area does not appear to be contaminated.

Station 33: Winter killed ground cover; no seepage visible through snow.

Station 34: Overflow from trench has been temporarily stopped by new berm; no visible colour difference in grass where leachate had flowed and where it had not.

Station 35: Vegetation gap has healthy ground vegetaion and top-killed cedars; active ground water seepage; no leachate effects detected at this time.

Station 36: Iron stained spring and active ground water seeps; main vigorous spring has very heavy iron staining conductivity 1400 us, temperature 9.5°C. Located in wooded area; seeps have conductivity of 460 us. No environmental impact visible.

Station 37: Clear cut area; dead cedar boughs cover ground.

Station 38: Seepage along stream bank: temperature 3°C, and 500 us conductivity; stream temperature in 3°C with conductivity of 1150 us.

Station 39: Seepage along stream bank and associated dark staining of water for less than .5 m; seepage temperature 5°C; conductivity is 2000 us.

Station 40: Leachate from small seep from landfill runs along access road for several metres (less than .1 m wide).

Station 42: Leachate seepage occurring from landfill toe.

Station 43: Area of leachate seepage observed in spring has dried up.

## 5.0 ARCHIVAL ANALYSIS

Comparison of site topography viewed on the 1954 and 1978 photographs defines the extent of main landfilling activity at Cobourg. The mound created by the original landfill, the new slope created by the current landfill and the 'bench' formed by disposal of burned refuse can be identified as changes in the original physical environment. However, the archival photography did not delineate the locations of scattered pockets of waste that were buried within the sand and gravel pit duing this time period, with the exception of a small disturbed area noted north of the creek.

From interpretation of the pre-landfill and 1978 photography, a hydrogeologist can predict that leachate discharge will concentrate at the toe of the fill, adjacent to the stream, and possibly in the shallow sands downstream of the landfill. In addition, some discharge may occur directly into the buried stream, depending upon the condition of the culvert. This general discharge pattern was observed around the original landfill mound in 1974; however, installation of the toe drain has reduced leachate discharge.

In addition, analyses of the 1978 photography locates two potential impact zones. While the overflow of the recharge trench is definitely a leachate impact, the gaps observed in the tree cover cannot definitely be attributed to the landfill. Field checking failed to link the gap closest to the site with landfill impact at this time, and found that the second gap is due to logging.

## 5.2 Photography Indicators - 1980

Colour and colour infrared photography identified leachate discharge and spills by direct and indirect detection. The main indicators are staining, vegetation effects and soil wetness. However, these indicators were frequently neither definitive nor unique in the environment and field checking was required to confirm a relationship between a condition identified on the photography and that identified on the ground at the landfill.

a) Staining

Red-brown staining of grass cover identified leachate discharge and overflow from the recharge trench. Staining is greatest in spring, when discharge is at a maximum. At this time, it is fairly definite indicator - the leachate red-brown stain just north of the landfill is characterized by a "stream-like" appearance. However, in summer, the area of red-brown stain is smaller, fainter and inconclusive - similar tones are visible downstream of the site where cut cedar boughs cover the ground. Staining is not visible in winter or autumn photography.

In addition, the colour of the indicator changes on the colour infrared film. In spring the red-brown staining has a blue tone which contrasts poorly with the soil background - and the staining is clearer on the colour imagery. In summer, however, the staining appears as a bright yellow-green tone on the colour infrared - and is clearer on the colour infrared photographs.

b) Vegetation Effects

Positive vegetation stress is visible around the overflow from the recharge trench because of increased soil moisture. It is particularly clear at the west end of the trench, where a halo of healthy grass in summer and a zone of persistent green grass in autumn contrasts with the naturally stressed grass cover over the rest of the site.

Negative vegetation stress is visible in the tree cover downstream of the landfill. However, leachate seepage is associated with only one gap - a gap closest to the site, with dead trees and slightly stressed ground cover (orangey-red tone on colour infrared summer photography). The other two openings - one characterized by standing dead trees, and the other by red-brown tone caused by cut cedar boughs - are not related to the landfill.

Some negative stress (pink tones) was also observed on the colour infrared summer film in trees and ground cover close to the site. While some of this stress is related to the landfill, some will be natural.

c) Soil Wetness

Dark soil tones identify possible leachate seepage on the landfill. These were the only indicators observed on the winter photography; however, water from snowmelt would produce the same feature.

## 5.3 Thermography Indicators

In April and November, the thermography appeared very flat in the analog form. Therefore, all analyses were made using level-sliced data, which enhanced the thermal anomalies.

Bright distinct thermal anomalies identified ground water and leachate contaminated discharge along the valley upstream and downstream of the site. In some areas, vegetation masked discharge points producing a warm signature that appeared more similar to ponding than to discharge. There is no differentiation between leachate and uncontaminated ground water discharge - this has to be determined in the field.

Other bright anomalies identified burning refuse and warm leachate in the leachate recharge trench. They differed in shape from the seepage discharge.

Less sharp and less intense warm thermal anomalies are identified on the property close to Highway 401 and well up gradient of the landfill. The causes of these anomalies were not field checked, but they appear to relate to ponded water.

Several interesting observations can be made when analyzing the detection of discharge areas by thermography. The large leachate seepage area located east of the access road and north of the stream is not detected on the spring thermography, when seepage was most active; however, the area does appear as a warm anomaly in November, when there was no active seepage visible in the field. In addition, the leachate seepage zone along the creek just downstream of the site is not detected on either April or November imagery

- despite a 4°C difference in November between seepage and the background soil.

## 5.4 Sensor Evaluation

The archival photography of the Cobourg site can be interpreted to define the area of main landfill activity and to locate possible leachate discharge areas. However, the location of small landfilled areas, away from the main site, could not be distinguished on the photography - these areas are just grouped in with general sand and gravel extraction activities visible east of the site from 1965 to present.

With regard to specially flown 1980 photography, summer and spring imagery is most successful in identifying leachate discharge (Figure A.11). The summer colour infrared film was marginally more successful than the spring colour photography since the infrared film could distinguish vegetation stress in addition to the remnants of leachate staining. During spring the same indicators were observed on both photographs, although staining was clearer on the colour imagery.

The better performance of spring and summer photography, as opposed to the winter and fall, reflects the seasonality of leachate impacts at Cobourg in 1980. The most visible leachate discharges occurred in spring; by summer, leachate overflow had been stopped and the main heavily stained seep had largely dried up. As a result, the effects of impacts was decreasing throughout the year, and by November, observations were indistinct. While snow cover may have obscured seepage on the March photography, it is likely that this is a

FIGURE A.11

1980 SENSOR EVALUATION

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Late Winter | | | | |
| 1 | No observation | I | N | |
| 2 | No observation | I | I | |
| 3 | No observation | N | I | |
| 4 | No observation | N | I | |
| Spring | | | | |
| 5 | Leachate spring | Y | I | N |
| 6 | Leachate seep | Y | Y | N |
| 7 | Leachate seep | I | I | N |
| 8 | Leachate spill | Y | Y | N(detect trench) |
| 9 | Leachate spill | Y | Y | N " " |
| 10 | Ground water seepage | N | N | Y |
| 11 | Ground water seepage | N | N | N |
| 12 | Leachate seepage | N | N | N |
| 13 | Leachate seepage | N | N | N |
| 14 | Leachate seepage | N | N | Y |
| 15 | Contaminated seepage | N | N | Y |
| 16 | Burning refuse | Y | Y | Y |
| 17 | Gravel pit | Y | Y | I(bright) |
| 18 | Gravel pit | Y | Y | I(pond) |
| Summer | | | | |
| 19 | Stream channel | I | I | |
| 19A | Vegetation | N | I | |
| 20 | Leachate seep | I | Y | |
| 21 | Leachate seep | Y | Y | |
| 22 | Vegetation gap | Y | Y | |
| 23 | Vegetation gap (cut) | I | I | |
| 24 | Perimeter trees | I | I | |
| 25 | Leachate overflow | Y | Y | |
| 26 | Vegetation | N | I | |
| 27 | Vegetation | N | I | |
| 28 | Vegetation | N | I | |
| 29 | Leachate seep | Y | Y | |
| 30 | Bare soil on site | N | I | |
| 31 | Natural vegetation gap | Y | Y | |
| Autumn | | | | |
| 32 | Leachate seep | N | N | N |
| 33 | Vegetation | N | Y | N |
| 34 | Leachate overflow | Y | Y | N |
| 35 | Tree gap | I | I | N |
| 36 | Contaminated spring | N | N | Y |
| 37 | Trees cut | I | I | N |

FIGURE A.11

1980 SENSOR EVALUATION

(continued)

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Autumn - (cont'd) | | | | |
| 38 | Ground water seep | N | N | N |
| 39 | Contaminated seep | N | N | N |
| 40 | Leachate seep | N | N | N |
| 41 | Burning refuse | Y | Y | Y |
| 42 | Leachate seep | N | N | N |
| 43 | Dried leachate seep | N | N | I |
| 44 | Pond | Y | Y | I |
| 45 | Ground water spring | N | N | Y |
| 46 | Gravel pit | Y | Y | I(pond) |

Y - feature identified

N - feature not identified

I - inconclusive or incorrect indicator

period of very low leachate discharge at Cobourg, i.e. that there was no seepage to be detected on the landfill surface.

The photography was not able to detect all leachate discharge areas. An area (about 10 m by 30 m) of active seeps downstream of the site is identified indirectly by a few dead trees and slightly stressed ground cover in the summer colour infrared film. However, the majority of undetected leachate seeps are located downstream of the site and obscured by trees or, if they occur on the landfill, are too small to be resolved on the imagery.

Neither April nor November thermography provided enough thermal contrasts to accurately identify leachate seepage. Although detailed level-slicing was performed, the subdivision of warm thermal anomalies decreased the sharpness of the thermal signatures. True winter thermography may have proven more successful at locating seepage.

No single sensor or group of sensors were able to detect all leachate seepage at Cobourg. However, spring and summer photography identified a greater proportion of active leachate discharge areas than thermography - and with the added advantage of distinguishing between ground water and leachate discharge. Archival photography was able to locate possible leachate discharge areas and even some current impacts at this site.

## 6.0 CONCLUSIONS

At the Cobourg site, archival photography is able to identify the existence of the landfill and is effective in locating probable impact areas. As a result, it can be used to determine where the necessary field checking should concentrate at the site.

Specially flown 1980 colour and colour infrared photography identifies the larger, more visible leachate discharge areas. However, many off-site and very small outbreaks were not detected.

Thermography provides incomplete coverage of leachate discharge areas. Because the imagery does not distinguish between leachate and ground water springs, all features have to be field checked to confirm the ground conditions represented by the thermal anomalies.

Field checking is necessary to identify fully the small leachate seeps and leachate seeps in vegetated areas.

## 7.0 IMAGERY USED AT THE COBOURG SITE

### 7.1 Archival

Archival photographs used at this site are:

| Year | Scale | Photo Number | Source |
|---|---|---|---|
| 1954 | 1:15840 | 4400-13 # 76-77 | M.N.R. |
| 1959 | 1:30000 | A16867 # 118-119 | N.A.P.L. |
| 1965 | 1:20000 | A18742 # 48-50 | N.A.P.L. |
| 1971 | 1:15840 | 4341-32 # 91-92 | M.N.R. |
| 1978 | 1:10000 | 4369-50 # 155-156 | M.N.R. |

### 7.2 1980 Imagery

Figure A.4 shows the area covered by the 1980 imagery. Scales, date and target photographs are given for each imagery set.

### 7.3 Sources

A complete set of imagery is available for viewing at the following offices of the Ontario Ministry of the Environment:

Solid Waste Unit
Waste Management Branch
Ontario Ministry of the Environment
4375 Chesswood Drive
Downsview, Ontario
M3J 2C2

Central Region
Ontario Ministry of the Environment
Suite 700
150 Ferrand Drive
Don Mills, Ontario
M3C 3C3

West Central Region (Hamilton Region Office)
Ontario Ministry of the Environment
140 Centennial Parkway North
Stoney Creek, Ontario
L8E 3H2

Copies of imagery may be obtained from:

1980 imagery - Contact Ministry of the Environment Offices.

Archival:

N.A.P.L.: National Air Photo Library
Energy Mines and Resources
615 Booth Street
Ottawa, Ontario
K1A 0E9
Telephone: (613) 995-4560

M.N.R.: Public ServiceCentre
Ontario Ministry of Natural Resources
Whitney Block
Queen's Park
Toronto, Ontario
M7A 1W3
Telephone: (416) 965-1123

# Appendix B
# Whitby site

## Remote Sensing Techniques & Waste Management Assessments

# 1. INTRODUCTION

The Whitby landfill site is located 9 km north of the Town of Whitby, overlooking Lynde Creek (Figure B.1). It is one of six southern Ontario landfills used in the study "Remote Sensing Techniques and Waste Management Assessment", prepared for the Ontario Ministry of the Environment. The study purpose is to evaluate specific remote sensing techniques for application to landfill monitoring and identification.

Colour and colour infrared aerial photography, and thermography was acquired during 1980. This imagery, along with archival photography, was interpreted for application in monitoring and identifying existing landfill sites. A summary of the results, comparative evaluation of techniques and final study conclusions are presented in Volume 1 of this report.

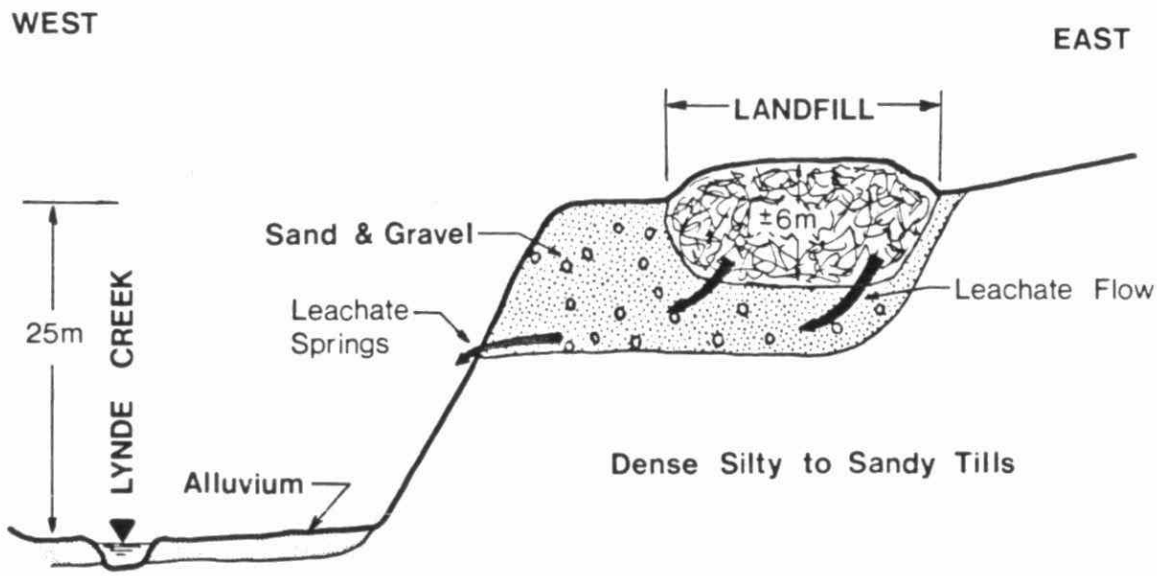
This appendix contains the detailed results for the Whitby site only. The appendix is one of six similar appendices comprising Volume 2. Together they provide all the detailed observations and data accumulated during this study. Each appendix is designed to be used separately with Volume 1, (the general text) if desired.

## 2. BACKGROUND

### 2.1 Physical Setting

The Whitby landfill was developed in a former sand and gravel pit, adjacent to Lynde Creek. The sands and gravels overlie dense silty sand till to sandy silt till. Lynde Creek has cut a deep valley into the overburden, exposing the contact between the sand and till along its valley wall. Alluvial soils cover the wide valley floor. Figures B.2, B.3 and the cross section sketch below show this general physical setting.

Schematic Cross Section of Whitby Landfill



Ministry of the Environment
Ontario

# B·1 Location map

● SITE LOCATION

0 10km

## Remote Sensing Techniques & Waste Management Assessment


**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Ministry of the Environment
Ontario

# B·2 Physical setting

- LANDFILL SITE
- SAND AND GRAVEL
- TILL (SILTY SAND AND SILT TILLS)
- STEEP VALLEY LANDS
- ALLUVIUM
- WATER COURSES

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Perennial ground water seepage emanates at the sand/till contact in the valley wall. Adjacent to the landfill this seepage contains a considerable amount of leachate. Contaminants leached from the garbage move vertically laterally through the permeable sands towards the Creek. Leachate discharges at the contact between the permeable sand and the slowly permeable till along the valley wall.

Ground and surface water investigations carried out for the Regional Municipality of Durham indicate that the leachate flows down the valley wall, and into the alluvial soils. From there, it moves through the shallow alluvium downstream towards Lynde Creek and the man-made pond just east of the creek. Minor contaminated ground water discharge is observed here.

Another small leachate seepage area occurs on the north side of the landfill, along the small stream valley.

## 2.2 Site History

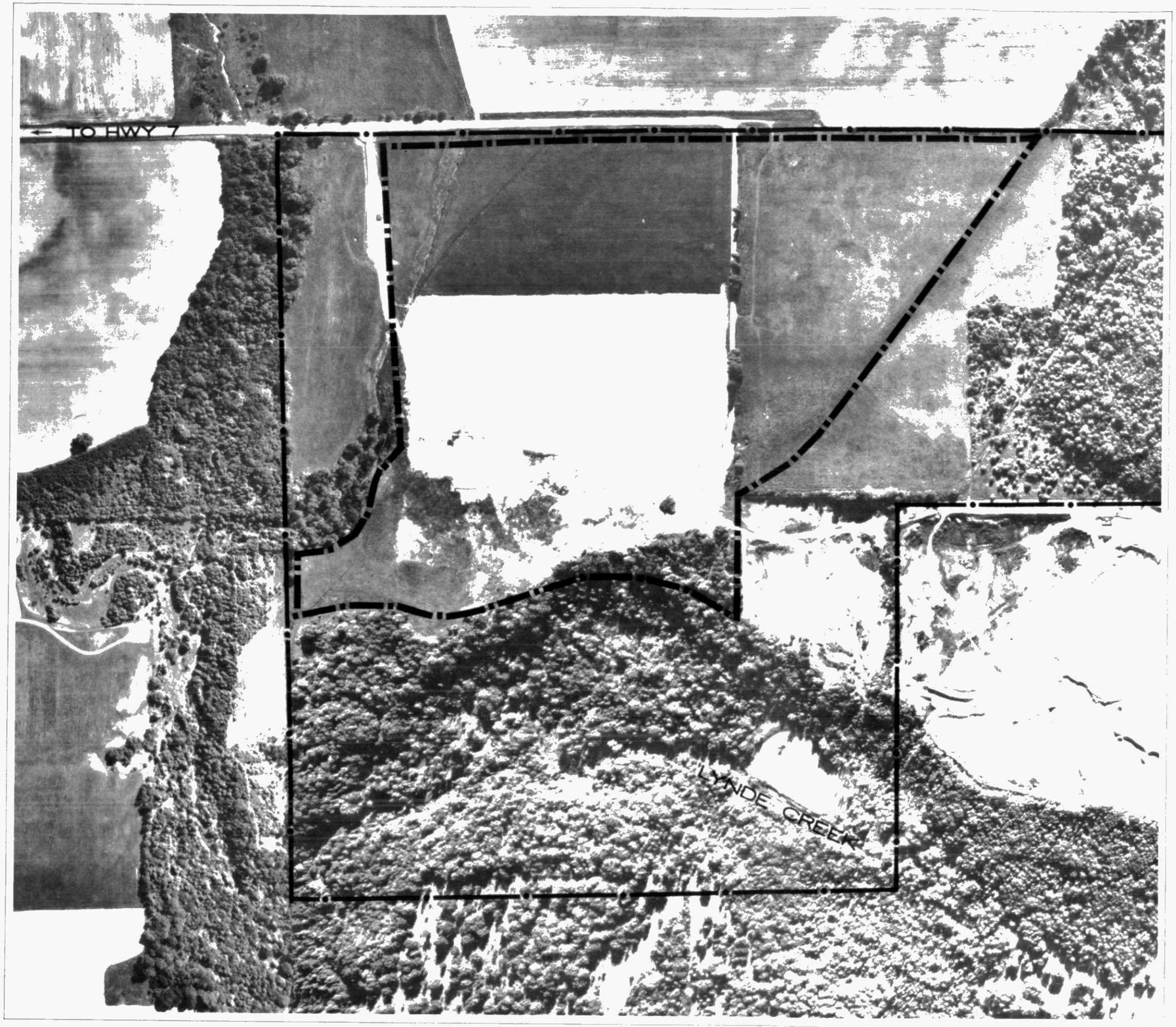
In operation since 1968, the Whitby landfill site is a municipally owned and operated site. Now operated by the Regional Municipality of Durham the site was previously operated by the Town of Whitby. Initially (1968-1969) burning was carried out to reduce the bulk of certain wastes.

A ground water monitoring program was initiated in 1970 and in 1974 potential leachate discharge to Lynde Creek was evidenced.

Records indicate the site is approximately 9 hectares with a daily rate of landfilling of approximately 63 tonnes and serving a population of 23,000 persons.

By 1978 it was noted that leachate discharging from valley slopes of Lynde Creek had increased significantly. Monitoring programs and assessments undertaken earlier concluded that leachate discharge in this area was expected.

In 1979, the site reached final contours and a layer (minimum 0.6 m) of earth cover was applied and graded. Although an expansion to site operations is planned the site has not been used for landfilling since 1979.




Ministry of the Environment
Ontario

# B·3 Site plan

PROPERTY BOUNDARY

CONSERVATION AUTHORITY BOUNDARY

NO LEACHATE COLLECTION SYSTEM

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

## 3.0 METHODOLOGY

The prime objective of the study was to evaluate remote sensing techniques for thier applicability to waste management programs. Six sites were selected for the study and a program for acquisition of remote sensing data for the sites was developed.

Four remote sensing techniques were selected for study:

i) archival photography
ii) colour aerial photography
iii) colour infrared aerial photography
iv) aerial thermography

Each sensor was expected to be capable of providing specific data on the condition of each site - in particular the discharge of leachate (colour aerial photography and aerial thermography). The sites selected represented a range of differing hydrogeological conditions, with a known history of surface discharge of leachate, and with various stages of site operation and site rehabilitation.

The selected sites were:

Cobourg Landfill Site
Whitby Landfill Site
Oakville Landfill Site
Bayview Park Landfill Site (in Burlington)
Burlington Landfill Site
Upper Ottawa Street Landfill Site -
(in Hamilton)

The program for evaluation of sensors comprised initially the acquisition and review of hydrogeological assessments made

for the site through previous studies. In addition, to assist in providing an understanding of site history and past operations, archival photography was obtained dating back to pre-landfill conditions and taken at intervals ranging from 5 to 7 years. To further assist in constructing a site development history, a review of Ministry files for the site was made. Observations of site operations and leachate discharge were reported and give insight on the development of leachate mounding and on operational procedures which have conributed to present site conditions.

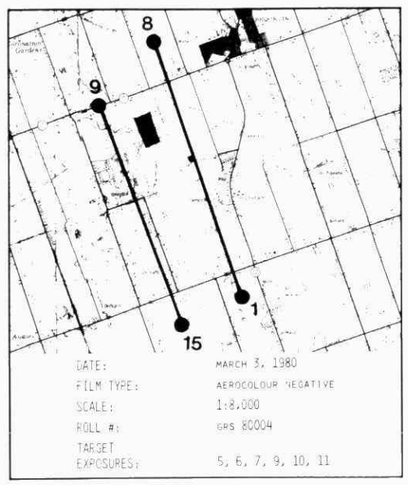
The schedule for remote sensing data acquisition at Cobourg was:

| Sensor | Flight Date | Field Reconnaissance |
|---|---|---|
| colour photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 30 April 1980<br>August 1980<br>19 November 1980 |
| colour infrared photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 30 April 1980<br>August 1980<br>19 November 1980 |
| thermography | 17 April 1980<br>26 November 1980 | 30 April 1980<br>August 1980<br>19 November 1980 |

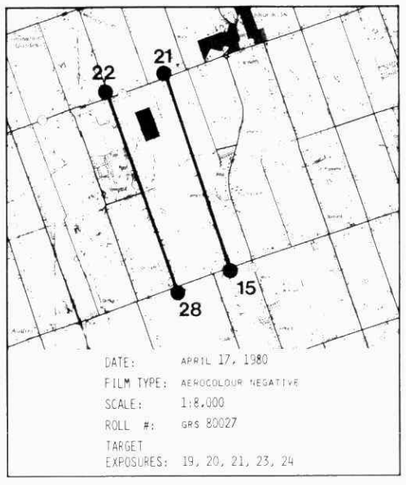
Photography scale was changed from 1:8000 for March and April flights to 1:6000 for July and November flights. Average flying altitude for thermography was 1050 m, giving an approximate scale of 1:14000. Data acquisition details are given on Figure B-4.

After each flight, photography and imagery were examined and preliminary interpretations made. Detailed field reconnaissance was made to confirm interpretations and to

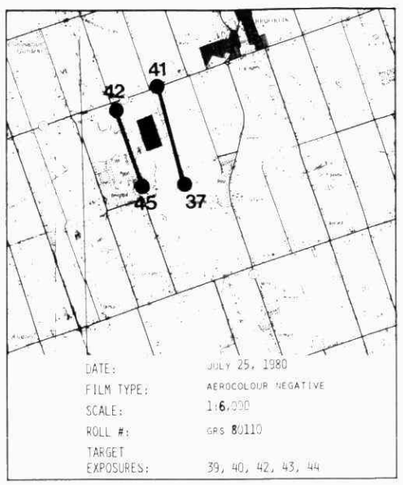
TRUE COLOUR



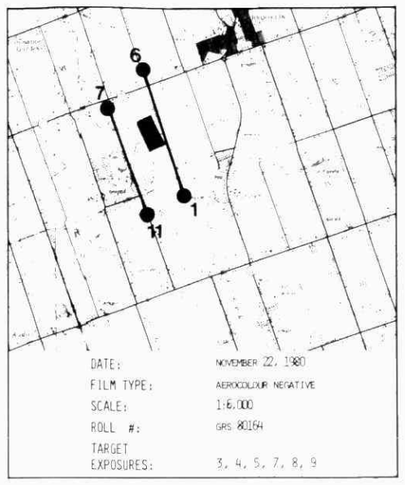

DATE: MARCH 3, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80004
TARGET EXPOSURES: 5, 6, 7, 9, 10, 11




DATE: APRIL 17, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80027
TARGET EXPOSURES: 19, 20, 21, 23, 24

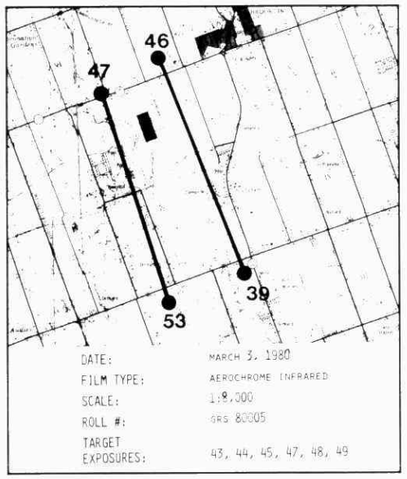



DATE: JULY 25, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:6,000
ROLL #: GRS 80110
TARGET EXPOSURES: 39, 40, 42, 43, 44

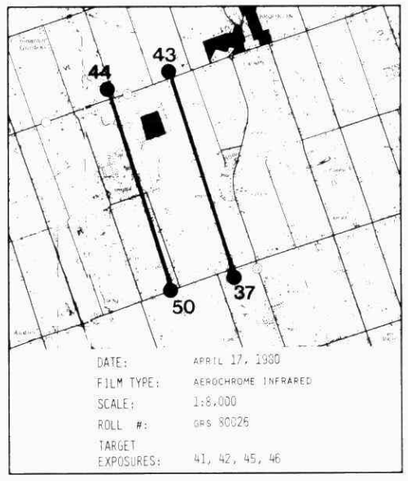



DATE: NOVEMBER 22, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:6,000
ROLL #: GRS 80164
TARGET EXPOSURES: 3, 4, 5, 7, 8, 9

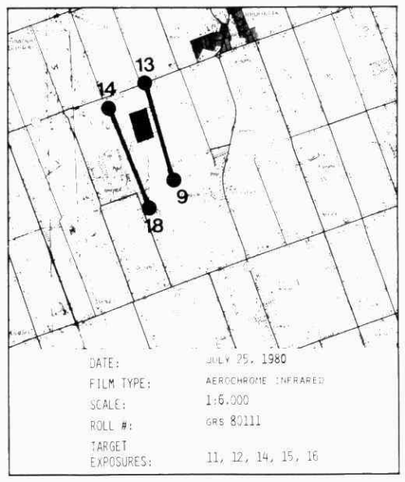
COLOUR INFRARED



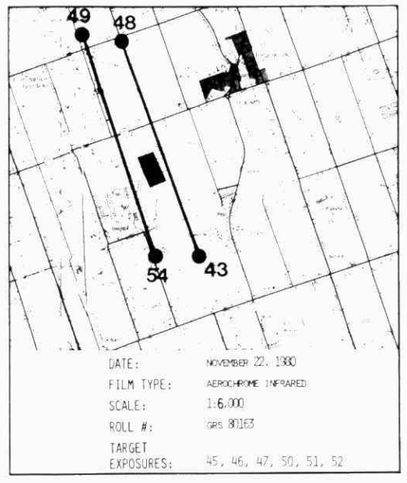

DATE: MARCH 3, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80005
TARGET EXPOSURES: 43, 44, 45, 47, 48, 49




DATE: APRIL 17, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80026
TARGET EXPOSURES: 41, 42, 45, 46

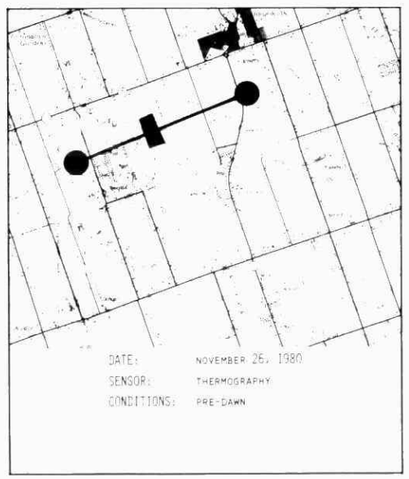



DATE: JULY 25, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:6,000
ROLL #: GRS 80111
TARGET EXPOSURES: 11, 12, 14, 15, 16

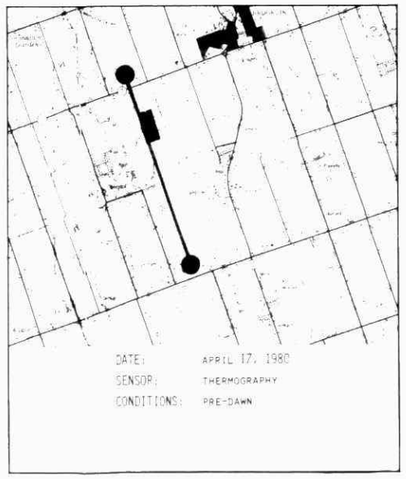



DATE: NOVEMBER 22, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:6,000
ROLL #: GRS 80163
TARGET EXPOSURES: 45, 46, 47, 50, 51, 52

THERMOGRAPHY



DATE: NOVEMBER 26, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN



DATE: APRIL 17, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN

LATE WINTER | SPRING | SUMMER | AUTUMN

Ministry of the Environment
Ontario

# Whitby site

# B·4 Data Acquisition (1980)

0 2 kilometres

## Remote Sensing Techniques & Waste Management Assessment


**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

identify any features undetected on the sensors. Photography and imagery for each flight were annotated and annotations for subsequent flights compared so that assessment of the relative effectiveness of sensors under varying seasonal conditions would be made.

Following completion of all data acquisition, interpretations and field work, comparative assessments of data with respect to season, sensor type, and type and extent of features sensed were made. Site features detectable in the field were noted and compared to those interpreted from photography and imagery. These records and interpretations were used as a basis for determining the effectiveness of each technique.

The relative merits of the various sensors in satisfying the study objective and taking into account relative costs of data acquisition were then assessed.

## 4. STUDY RESULTS

### 4.1 Archival Photography

The black and white existing photography shows the development of the site from farmland in 1954, to interim closure of the landfill in 1978. Data sequences are plotted on Figure B.5.

Several features are interpreted on the photographs which identify the extent of refuse and the location of probable future impacts. These include:

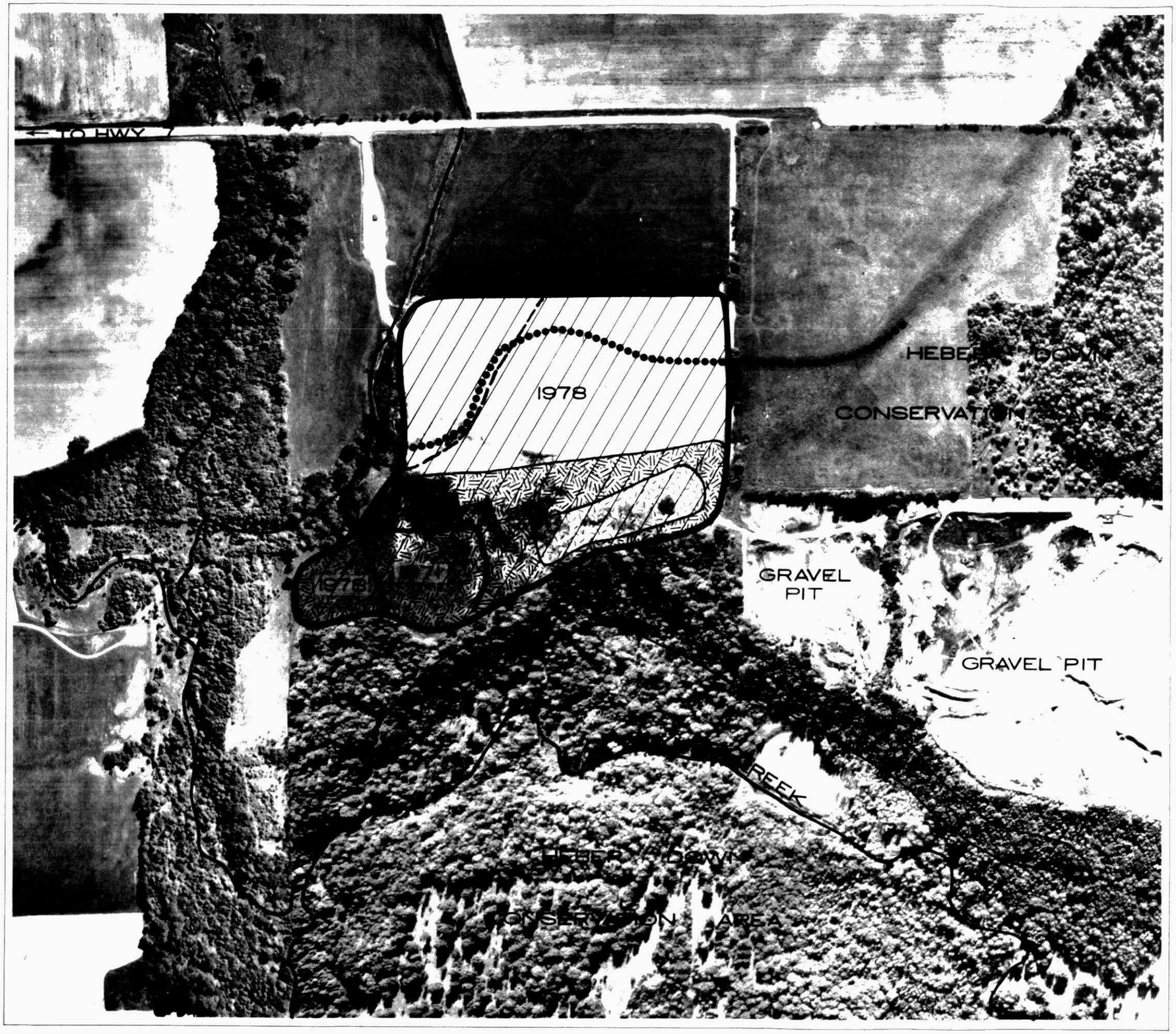
i) the original extent of sand and gravel beneath the site (1964);

ii) vigorous cedar growth on the east valley wall suggesting a zone of considerable ground water seepage (1964, 1971);

iii) the original course (1964) and subsequent landfilling (1971 to 1978) of a small runoff channel that crosses the northeast part of the site; this former drainage channel roughly corresponds to a leachate seep on the north side of the site;

iv) the full extent of landfill excavation along the crest of the valley (1971); revegetation obscures the northern tip of the landfilled area on 1978 photography.

By 1978, the original site is almost filled. Landfill activity is indicated by disturbed land surface (poor vegetation cover) and site buildings. During 1979, additional refuse was added to the site creating a slight mound. In




Ministry of the Environment
Ontario

Whitby site

# B·5 Archival photography

PRE-LANDFILL CONDITIONS

WATER COURSES

PIT (1964)

PROBABLE SEEPAGE ZONES

SAND-TILL BOUNDARY

LANDFILL CONDITIONS (1971 TO 1978)

ABANDONED PIT (EXTENT IN 1971)

EXTENT OF LANDFILL AREA IN 1971 AND IN 1978

NOTE: PHOTOGRAPHY FROM 1954, 1964, 1971 AND 1978.

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

1980, the site was then covered and recontoured to reduce precipitation infiltration and the surface drainage east of the site was diverted in preparation for expansion (see Figure B.2).

## 4.2 Late Winter Data 1980

### 4.2.1 Sensing Conditions

The imagery acquired in the first week of March was originally intended to study winter conditions. Unfortunately snow fall was abnormally low in the winter of 1979/80 and, at the time of photography, snow accumulations were generally confined to protected areas. Continuous snow cover may have given better conditions for observing leachate seepage (i.e. better contrast on photography). Weather data for the week preceding 4 March 1980 are listed on Figure B.6.

Thermography was acquired 28 March during daylight hours. Results were not suitable for the study.

### 4.2.2 Diagnostic Features

Imagery observation points are located on Figure B.7 and outlined below.

a) Colour Photography:

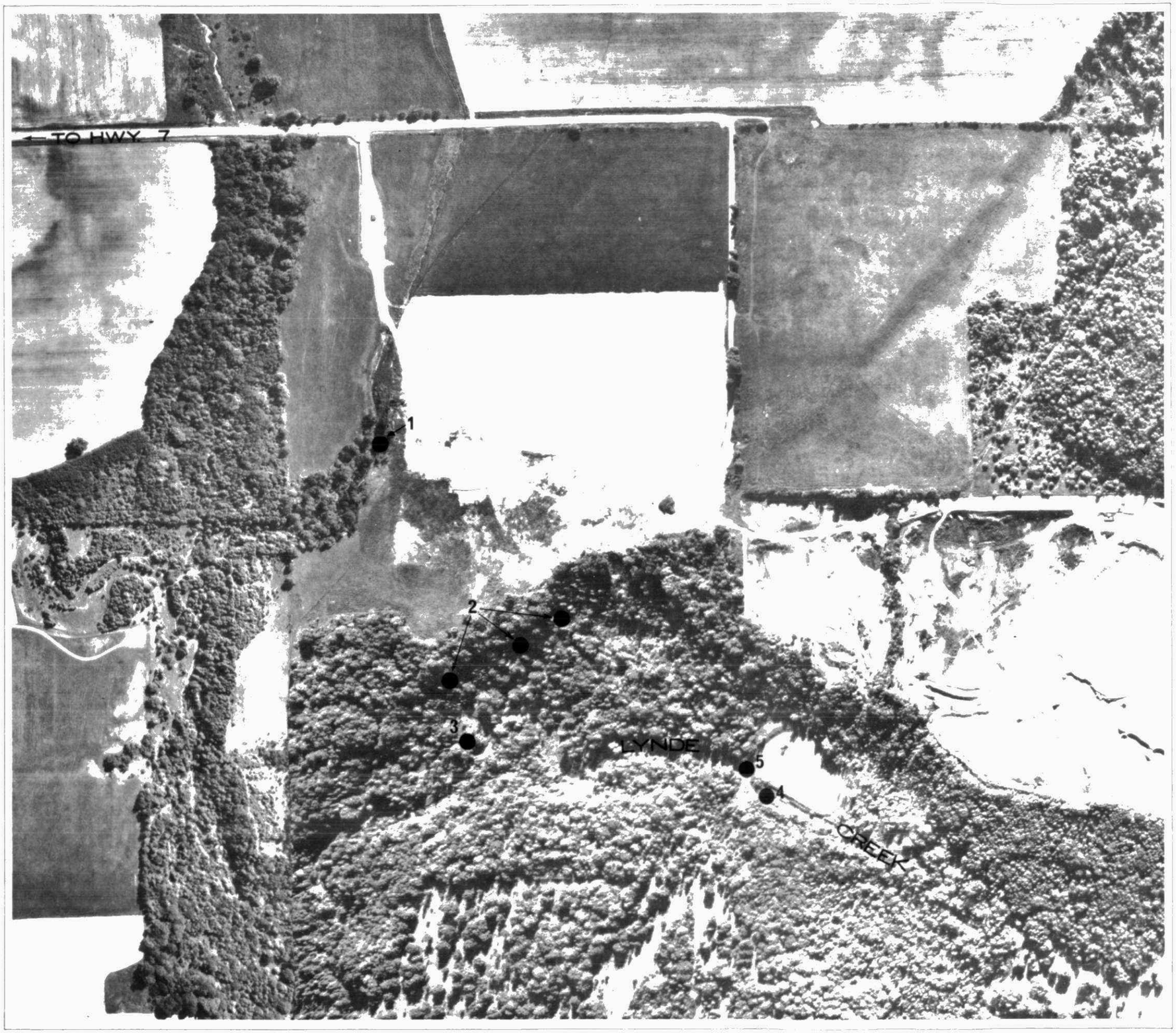
Two features on the colour photography indicate leachate seepage:

FIGURE B.6

WEATHER DATA[1]: WHITBY LANDFILL

| DATE | TEMPERATURE (°C) | | | |
|---|---|---|---|---|
| | Maximum | Minimum | Mean | Precipitation[2] |
| **Late Winter** | | | | |
| February 27 | - 2.0 | -10.0 | - 6.0 | |
| 28 | -11.0 | -18.0 | -14.5 | |
| 29 | -14.0 | -24.0 | -19.0 | |
| March 1 | -13.0 | -20.0 | -16.5 | |
| 2 | - 6.5 | -20.0 | -13.0 | |
| 3 | - 1.0 | -15.5 | - 9.0 | |
| 4 | 2.0 | - 5.5 | - 2.0 | |
| **Spring** | | | | |
| April 12 | 9.0 | 3.5 | 6.0 | 9.4 (R) |
| 13 | 9.0 | 1.0 | 5.0 | |
| 14 | 9.0 | 0 | 4.5 | 10.6 (R) |
| 15 | 6.0 | 3.0 | 4.5 | 1.8 (R) |
| 16 | 3.5 | - 4.5 | .5 | |
| 17 | 2.0 | - 4.0 | - 1.0 | |
| **Summer** | | | | |
| July 20 | 26.0 | 17.5 | 22.0 | 17.8 (R) |
| 21 | 29.8 | 17.5 | 23.0 | 1.6 (R) |
| 22 | 23.0 | 16.0 | 21.0 | 1.4 (R) |
| 23 | 26.0 | 16.0 | 21.0 | |
| 24 | 25.0 | 16.5 | 21.0 | |
| 25 | 25.0 | 14.0 | 18.5 | |
| **Autumn** | | | | |
| November 16 | 0 | - 5.5 | - 3.0 | |
| 17 | 0 | - 6.0 | - 3.0 | 1.0 (S) |
| 18 | 2.0 | - 3.0 | - .5 | |
| 19 | 3.0 | - 4.5 | - 1.0 | |
| 20 | 5.5 | - 3.0 | - 1.5 | |
| 21 | 6.0 | 3.5 | 5.0 | 2.0 (R) |
| 22 | 6.0 | 0 | 3.0 | |
| 23 | 6.5 | .5 | 3.0 | 1.2 (R) |
| 24 | 7.5 | 3.5 | 5.0 | 2.4 (R) |
| 25 | 2.5 | - 2.0 | 0 | 3.0 (S) |
| 26 | 5.0 | - 6.5 | - .5 | |
| 27 | 4.0 | - 1.5 | 1.0 | 7.0 (S) |

1. Source - Oshawa Airport Station
2. (R) rain in mm
   (S) snow in cm
   (Tr) trace in precipitation




Ministry of the Environment
Ontario

Abbyste

# B·7 Late winter data
## (March 1980)

●3 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80004-10
COLOUR INFRARED PRINT
– GRS80005-48

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

i) faint reddish-brown colour is just visible along the sand/till contact (Station 2); winter field observations record leachate discoloured ice sheets forming along here (Figure B.8).

ii) a small open pool occurs below the landfill (Station 1) all other surfaces are frozen and usually snow covered, suggesting this pool may be contaminated by warmer leachate. This pool is close to a diverted drainage course.

The following observations are listed by station number found on Figure B.7.

Station 1: A small open pool is visible just south of the water course; located below the waste; most other standing water is frozen and lightly snow covered.

Station 2: Faint reddish staining is visible in scattered pockets along the sand-till contact of Lynde Creek Valley; low contrast because of lack of snow cover under trees; corresponds to known leachate seepage which produces sheets of reddish stained ice in winter.

Station 3: Possible reddish staining in clearing on valley floor; indistinct.

Station 4: Open water along Lynde Creek corresponds to small area of fast water.

b) Colour Infrared Photography

Shadows obscure the valley wall on the colour infrared imagery and the features noted on colour photos are not visible. Wet soil (dark tone) on the pool shoreline is

seepage from a culvert from Lynde Creek, and is not a landfill related feature (Station 5).

## 4.3 Spring Data 1980

### 4.3.1 Sensing Conditions

Spring imagery was obtained on 17 April 1980, under good conditions - leaf free deciduous tree cover, high water table and runoff conditions. However, high soil moisture contents increased background noise on the thermography. Data was level-sliced to enhance thermal anomalies. Weather data for the week preceding acquisition are listed on Figure B.6.

### 4.3.2 Diagnostic Features

Imagery and field observations are presented below. Observations (station numbers) are located on Figure B.9.

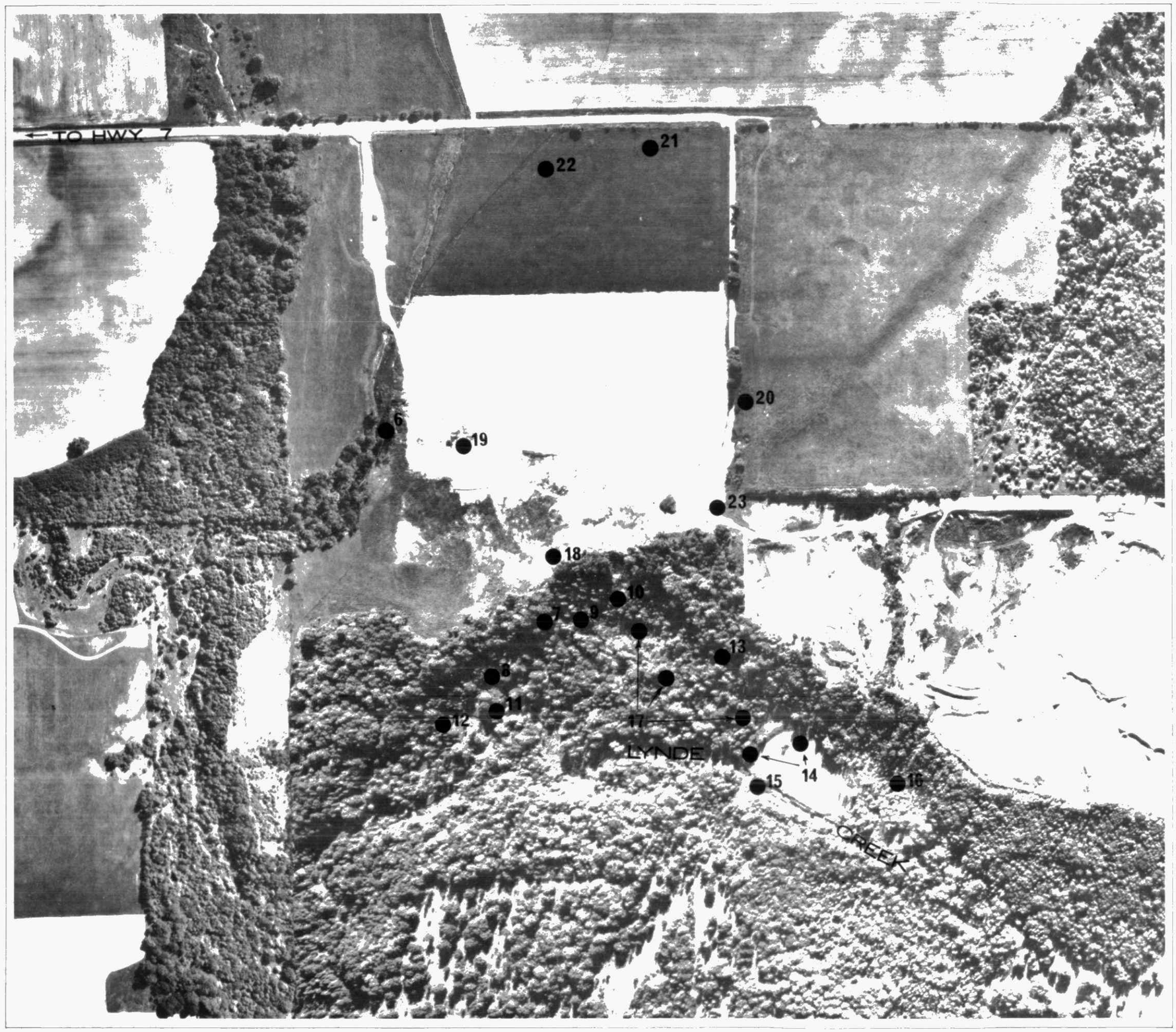
a) Colour

Faint reddish colouring is barely discernible along the sand/till contact below the landfill. There is little contrast between background and the staining. This observation is inconclusive as a single indicator of leachate seepage because similar tones are visible all along the treed creek valley.

Station 6: Small pool seen on winter photography is just barely visible; no sign of leachate staining apparent on photograph.

Station 7: Reddish-brown leachate staining is just visible along the sand-till contact in the valley wall. This was

Figure B.8 - Reddish brown ice forming at leachate discharge along Lynde Creek Valley; December, 1979.




Ministry of the Environment
Ontario

# B·9 Spring data
(April 1980)

●6 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80027-24

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

only visible after special development of this part of photograph to reduce interference from shadows. Similar tones downstream are not related to landfill.

b) Colour Infrared

Leachate activity is not visible on the colour photography. Long shadows, due to season and flying time, obscure most of the main leachate seepage area.

c) Thermography

High soil moisture contents increased the complexity of thermal anomalies on the April imagery for the Whitby landfill. Level-slicing was performed on the data in order to enhance warmer leachate outbreaks.

Leachate springs on the valley wall did not appear as discrete thermal anomalies. However, a warm zone is visible extending from the area of the springs, southward across the alluvium to the pond. This corresponds to known leachate movement but the warmth may indicate simple runoff ponding along a low area in the alluvium. Other thermal anomalies correlate with surface ponding.

The following are the characteristic thermal signatures from the thermography:

Station 17: Warm thermal anomaly extends from valley wall across flood plain; probably related to leachate seepage.

Stations 18-23: Relatively warm and extensive anomalies around the landfill are probably ponded runoff. They have no real point-source of hot input that coult be attributed to leachate intrusion.

d) Field Visit

Field checking on 30 April 1980, easily distinguishes the zone of active leachate seepage. Dark red-brown staining occurs intermittently along the discharge area and where leachate seeps onto the valley floor below. While this staining is very clear in the field, the leachate does not contrast strongly enough with forest floor litter to make it readily visible on photography. Leachate seepage ceases once the southern boundary of the fill is passed.

Detailed field observations follow (station locations are found on Figure B.9):

Station 8: Major side hill seepage along sand-till contact, downslope of landfill; spongy, discoloured surface; no surface flow from seeps (flow in topsoil/organic layer) in winter, leachate forms ice sheets; excavated at 1 seep to collect about 5 ounces per minute; temperature 8°C conductivity 6000 ± us.

Station 9: Seep from sand-till contact emanating on flat alluvial plain; heavy staining; conductivity 1800 ± us.

Station 10: Several leachate springs on hillside and flat alluvial plain; visible staining; temperature springs 6°C; conductivity 3500 ± us.

Station 11: Ground water installation - water table 12" ±; conductivity ground water sample 1900 ± us; surface water sample 2000 ± us.

Station 12: Spring and small pool covered with surface layer of "gunk"; gas bubbles base of pool; temperature of pool 8°C; conductivity of pool 700 ± us; conductivity of rivulet from pool 900 ± us.

Station 13: Natural seepage (uncontaminated); water temperature 2°C (ice under organic mat); conductivity 550 ± us.

Station 14: Minor seepage and staining along shore of pond; total about 10 ± gpm from approximately 10 springs; conductivity 450 ± us from springs and pond.

Station 15: Iron staining on rip-rap; no odor; unreliable conductivity value.

Station 16: Seepage occurring all along base of slope in this area; spring from east hillside; discharge about 50 ± gpm; conductivity 400 ± us; area silted from erosion.

## 4.4 Summer Data

### 4.4.1 Sensing Conditions

The full vegetaion cover condition on the 25 July 1980 photography (1:6000) provides the only opportunity to examine vegetation stress on the colour infrared film. Leachate impact is identified along the heavily treed valley wall and

valley floor. Weather conditions for the week preceding acquisition are listed in Figure B.6.

### 4.4.2 Diagnostic Features

Vegetation impacts are the main features on the summer photography. Observations are outlined below; locations are shown on Figure B.10.

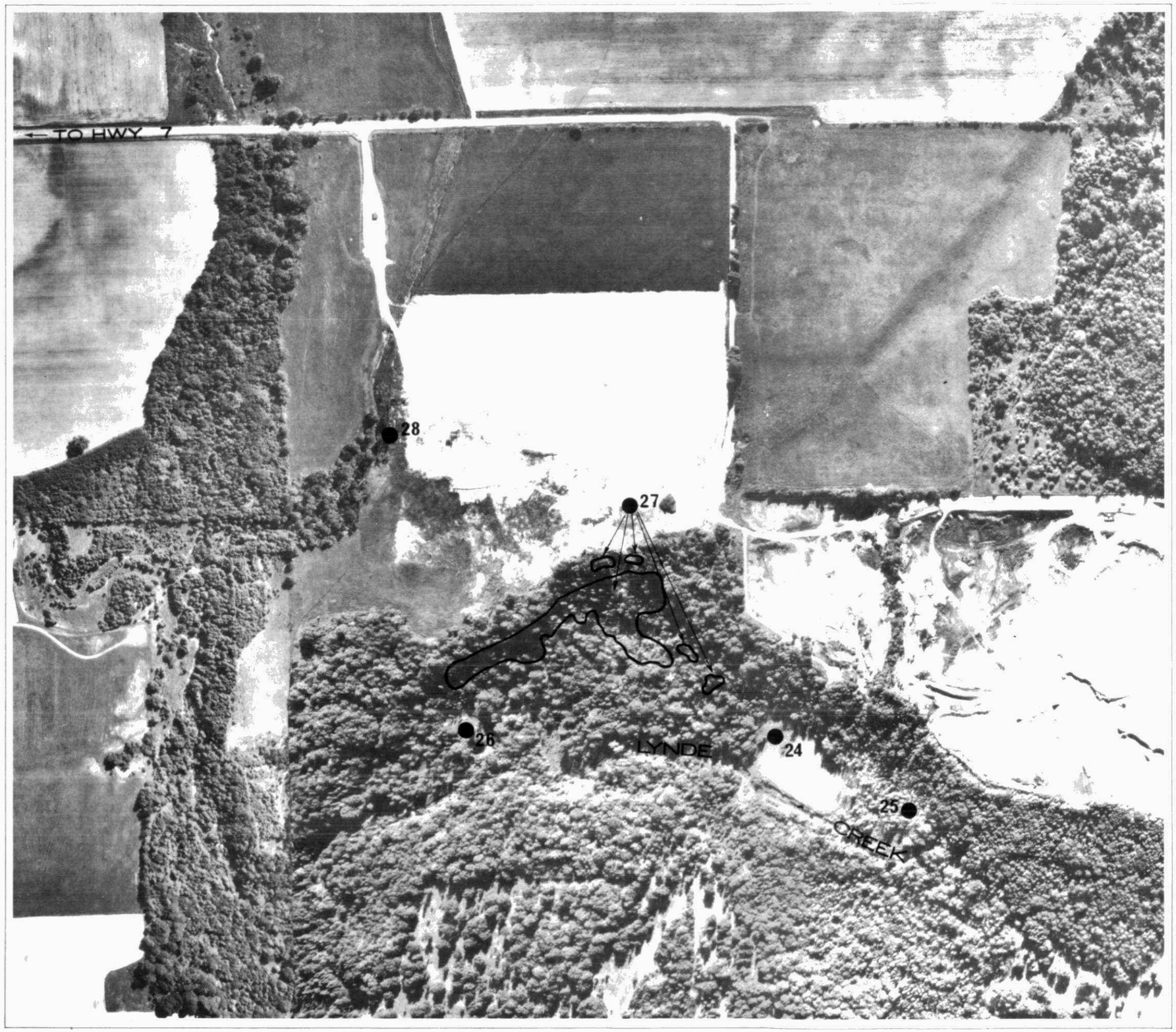
a) Colour

A zone of dead trees correlates with leachate springs emanating from the valley wall below the landfill. This impact area extends onto the valley floor, in a poorly defined "lobe" of individual dead trees and incomplete tree cover. The lobe extends from the south end of the seepage line towards the pond. Grey staining of the pond water along its northern shore suggests contaminated ground water inflow to the pond.

A second clump of dead trees, just south of the pond, are visible on the photography. These trees were killed by siltation.

Leachate staining is not visible despite lack of foliage in the main seepage area. Detailed observations follow. Refer to colour print GRS 80110-43.

Station 27: A zone of dead trees is visible along the valley wall and extending onto the flood plain. (Small clumps of dead trees (mainly cedars) are observed around the affected zone.)




Ministry of the Environment
Ontario

Whitby site

# B·10 Summer data
(July 1980)

● 23 STATION NUMBER AND LOCATION (PHOTOGRAPHY OBSERVATIONS ONLY)

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1 6000)
COLOUR PRINT – GRS80110-43
COLOUR INFRARED PRINT – GRS80111-15

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Station 24: Dark staining extends from the north bank of pond. Possibly weed growth.

Station 25: Area of dead trees on valley floor.

Station 28: No stress visible along stream.

b) Colour Infrared

The impact area below the landfill is more clearly defined by the greater contrasts on the colour infrared. The extent of stressed vegetation (trees and undergrowth) is more visible. In addition, the patches of leachate seepage staining can be detected (yellow-green tone).

Scattered vegetation stress is visible throughout the area. Some stressed areas, especially along the flood plain may be landfill related. However, much of the apparent stress is natural or not related to the landfill. Field checking of specific vegetation is required to confirm the relation of locally stressed vegetation to the landfill.

Detailed observations are listed below.

Station 27: Area of vegetation stress more accurately defined, with leachate seepage visible on upper part of slope. Vegetation with grey tones are dead trees. Dark red, pink, and blue-green tones are stressed and dead ground cover while yellow-green tone is probable red-brown leachate staining.

Station 24: Dark staining visible in pond; possible weed growth.

Station 25: Dead and stressed vegetation visible from grey and pink tones respectively.

Station 26: Vegetation stress in small wet area on flood plain; ground cover has pink tone.

Note: Scattered stressed trees and ground cover occur throughout area. Most are unrelated to landfill.

c) Field Observations

July field visit confirmed leachate seepage locations observed in April. Seepage was active along the valley wall and staining was visible at the pond.

## 4.5 Autumn Data 1980

### 4.5.1 Sensing Conditions

Photography, at 1:6000 scale, and thermography were acquired during November. The photography is similar to the spring colour and colour infrared imagery, showing leaf-free deciduous tree cover. Conditions were excellent for thermography. Cold nighttime temperatures provide a thermally flat background allowing easier detection of springs. Weather data for the week prior to November 1980 are listed in Figure B.6.

Low sun angles create very long shadows on the photography. This obscures many ground features, especially on the east slope of Lynde Creek valley. Shadowing effect is greater on colour infrared than colour film.

4.5.2 Diagnostic Features

Features described in the following text and observation locations are shown on Figure B.10.

a) Colour

Anomalous colour tones are the main diagnostic features. Heavy leachate seepage along the sand-till contact is detected as only small patches of dark red-brown staining.

A fringe of bright red-brown staining is visible along Lynde Creek just downstream of the weir (see also Spring Field Observations).

Station 31: A fringe of dark staining is just visible along shoreline of pond where extensive staining occurred in summer.

Station 32: A line of red-brown staining is visible for approximately 15 m against the grey rip-rap lining the east side of the Lynde Creek, downstream of weir.

Station 34-37: Scattered areas (few square metres) of dark red-brown staining on mid-slope.

Station 41: Light reddish brown tone of ground cover in natural fall vegetation colour; see area around 25 on west side of Lynde Creek.

Station 42: Leachate impact not visible on photography.

Note: The area of stressed to dead vegetation along the valley wall adjacent to the landfill recognizable by lower tree density.

b) Colour Infrared

Observation on autumn colour infrared are inconclusive. Refer to colour infrared prints GRS 80163-47 and 51, to compare tone changes in vegetation.

Station 41: Yellow-green tones, similar to leachate tones and natural dead vegetation at Cobourg are observed adjacent to landfill and west of Lynde Creek. This tone is of natural ground cover winter kill, and not leachate induced kill.

Station 40: All vegetation is stressed by onset of winter. However, coniferous trees at southern location appear to be more stressed (pinkish-grey) than trees to north (magenta). Similar lighting and camera angle should reduce photographic distortion effects.

Station 33: Individual coniferous trees on flood plain appear to be more heavily stressed than other trees; this coincides with area of vegetation stress clearly seen on summer photography.

c) Thermography

Thermal contrasts on the November analog imagery were adequate for leachate outbreak identification. "Noise" on the imagery results from a mechanical problem in taping the data during acquisition.

Leachate outbreaks are characterized, on the thermography by the following:

Stations 29, 30, 39: Bright thermal anomalies identifying seepage are muted by vegetation overstory. Stations 29 and 30 are definitely uncontaminated seepage.

Stations 34, 35, 36, 38: Warm thermal anomalies are just distinguishable from the background and correlate to known seepage areas; possibly muted by vegetation.

Station 43: Warmer area of pond, relates to flow from culvert joining pond to Lynde Creek; flow has prevented ice forming on surface (19 November 1980).

d) Field Observations

At the time of field trip (7 November 1980), there was a thin covering of snow. Observations made around site perimeter are listed below, and located on Figure B.11

Station 42: Leachate seeping into small pond in former drainage channel stains snow and ice on surface.

Station 37: Very active leachate seeps occur along sand/till contact from this location to approximately Station 34. Heavy staining is visible on ground and snow surface.

Station 33: Bright red-brown coloured seepage occurring through rip-rap lining east side Lynde Creek channel. Extends approximately 15 + m downstream weir; probable contaminated discharge.

# 5. ANALYSIS

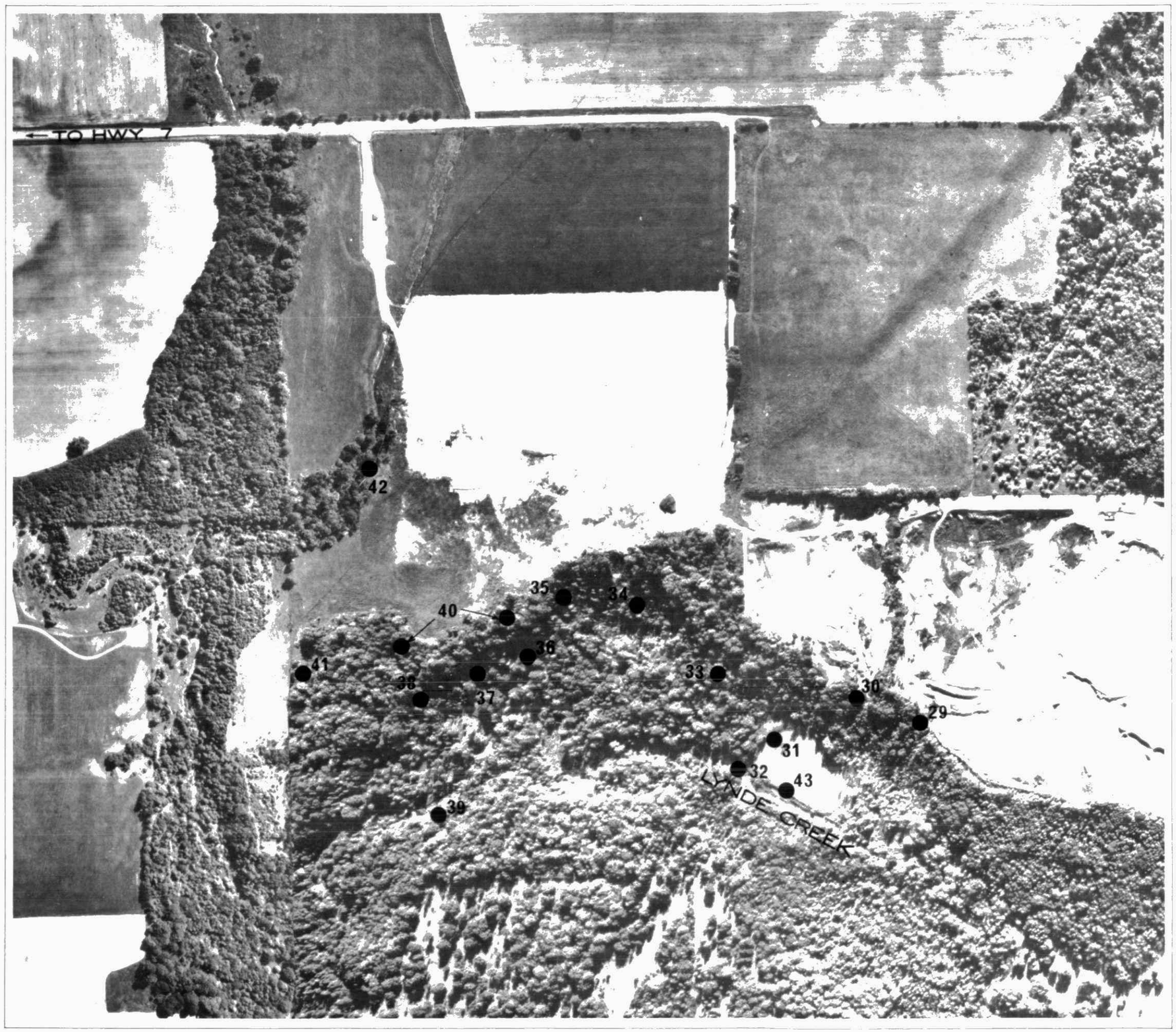
## 5.1 Archival Photography

Leachate seepage at Whitby can be readily predicted from the archival photography. The location of the main seepage zone along Lynde Creek rather than at the landfill toe results from the site geological setting (Section 2.1). By knowing the location of the landfill (1971 to 1978 photography) and the original geology and ground water seepage (1954, 1964 photography) an interpreter can predict that springs below the landfill will become contaminated. Seepage is likely to occur also at the landfilled gully on the north edge of the site.

Simple comparison of just the 1964 (pre-landfill) with the 1978 (late landfill) photography does not reveal the full extent of the landfilled area. Revegetation in 1978 obscures the northern "arm" of the landfill. However, intervening photograpy (1971) shows the full extent of the landfill excavation.

## 5.2 Photography Indicators - 1980

The key indicators of leachate (observed on the imagery) at Whitby in 1980 are vegetation stress, surface staining and unfrozen ground. Leachate seepage occurred mainly in a well treed zone and heavily stained the surface at the discharge point. Non-landfill related features, resembling the landfill indicators, were also observed.




Ministry of the Environment
Ontario

Whitby site

# B·11 Autumn Data
(Nov. 1980)

●32 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:6000)
COLOUR PRINT
– GRS80164-8
COLOUR INFRARED PRINT
– GRS80163-47

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

a) Vegetation Stress

The major zone of leachate seepage at Whitby is well defined by vegetation stress visible on colour and colour infrared summer photography. A line of dead trees along the east valley wall correlates with vigorous leachate seepage along the sand-till contact. Clumps of dead trees (and stressed vegetation visible on the colour infrared photography) suggest that leachate impact is occurring along the valley floor, moving downstream towards the pond. This correlates with previous ground and surface water investigations of the migration of contamination towards Lynde Creek.

A second clump of dead trees downstream of the pond are not related to leachate impact. Despite their proximity to the site, stereoscopic interpretation and knowledge of general hydrogeology suggested that these trees were unlikely to have been damaged by leachate seepage, and would not require field checking. Damage was caused in fact by siltation.

Vegetation stress is observed in individual trees and pockets of ground cover scattered over the study area. Some stress close to the site along Lynde Creek may be due to leachate impacts. However, similar stress occurs well beyond the landfill influence as a result of natural or other man-made causes.

Therefore, the existence of stress is not proof of impact. It has to be related to the landfill, and then the cause of stress confirmed in the field.

b) Surface Staining

Detection of the heavy red-brown staining along the seepage zone is incomplete and often inconclusive on the colour

photography. During leaf-free conditions, the staining appears patchy and faint on the photography failing to convey the vigor and full extent of leachate seepage. On the spring photography, the colour is not unique - similar tones are seen all along Lynde Creek valley. In summer, the leachate staining is not detected at all despite the open branches of dead tree cover.

Low contrast with the forest floor leaf litter is probably the main problem for colour imagery detection. The reddish--brown ice sheets which form along the seepage zone in winter (Figure B.8) and which are just visible on the March photos, may have been clearer if snow cover had been continuous.

Red-brown staining appears on the summer colour infrared (yellow- green tone); however, shadow and/or lack of contrast prevents detection of staining at any of the other three seasons.

c) Unfrozen Ground

A small, apparently open pool of water is just visible on the colour photography in March, along the small drainage channel north of the site (Station 1, 42). All other stationary water is frozen and snow covered; leachate seepage into this pool has apparently prevented snow from accumulating on the surface. This is the only indicator identifying this leachate seep.

## 5.3 Thermography Indicators

Leachate outbreaks at the Whitby landfill were not detected on the thermography. However, level-slicing of both the November and April imagery provided some thermal contrast and some possible indicators of seepage activity.

The seepage areas along the treed wall of the stream valley appear brighter (warmer) than the background in the November thermography. It is possible that the radiated heat energy from the leachate seepage points is being muted by an over-story of coniferous trees. Unfortunately, the same thermal signature can be created by the coniferous trees which grow in this area. As well, and because there is no defined point source identification, the anomaly could be attributed to moisture accumulation in the leaf litter layer.

The November thermography showed a warm area along the west edge of the pond. Field checks found this was due to water discharge from a culvert.

The April imagery, when level-sliced, revealed a warm elongated signature which extends from the leachate seepage zones to the pond. This pattern could be an indication of the drainage system zones or ponding on the flood plain. Other warm thermal signatures in the valley also appear to be associated with a drainage network and did not have the bright, sharp signature of a leachate related phenomenon.

## 5.4 Sensor Evaluation

Archival photography was the best and most cost effective of the techniques investigated. These photographs - dating from 1954 to 1978 - provided a good source of information on the

sequence of landfilling and allowed the interpreters to predict probable lechate flow directions.

The colour photographs provided rather disappointing results (Figure B.12) since it was very difficult to distinguish the red leachate stains against the ground cover mainly because of the trees. The summer colour photography, provided better information because we could relate the leachate seeps to clumps of dead trees.

Colour infrared provided good information from the summer photography (Figure B.12). This is not surprising since the major leachate seepage is occurring in heavy vegetation. Greater tonal contrasts and stressed vegetation areas provided the most accurate definition of the leachate seeps in this summer photography. Colour infrared, however, provided very poor results during the other seasons.

The thermography was only available for the spring and the fall. It is possible to identify anomalies that corresponded to some of the leachate seeps. However, all of the anomalies were inconclusive and could be attributed to other features in the environment.

No one individual sensor accurately determined all of the leachate outbreaks in one season, although seepage and impacts were identified by the three 1980 sensors combined. The size of the leachate seepage, the seasonal changes in vegetation cover, the variations in seepage discharges and temperature difference all combined to prevent identification of all leachate outbreaks by any one remote sensing device. However, the interpretation of the archival photography provided a prediction of where seepage would probably occur. But it did not include a prediction of associated leachate impact zones away from the discharge points.

FIGURE B.12

1980 SENSOR EVALUATION

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Late Winter | | | | |
| 1 | Leachate seep | Y | N | |
| 2 | Leachate stain | Y | N | |
| 3 | Leachate stain | Y | N | |
| 4 | Turbulent water | I | N | |
| 5 | Culvert outfall | N | I | |
| Spring | | | | |
| 6 | Leachate seep | I | N | N |
| 7 | Leachate seep | I | N | N |
| 8 | Leachate seep | I | N | N |
| 9 | Leachate seep | I | N | N |
| 10 | Leachate seep | I | N | N |
| 11 | Ground water seep | N | N | N |
| 12 | Spring | N | N | N |
| 13 | Ground water seep | N | N | N |
| 14 | Ground water seep | N | N | N |
| 15 | Ground water seep and Stain | N | N | N |
| 16 | Ground water seep | N | N | N |
| 17 | Vegetation & valley floor | Y | Y | I |
| 18 | Ponded runoff | Y | Y | Y |
| 19 | Ponded runoff | Y | Y | Y |
| 20 | Ponded runoff | Y | Y | Y |
| 21 | Ponded runoff | Y | Y | Y |
| 22 | Ponded runoff | Y | Y | Y |
| 23 | Ponded runoff | Y | Y | Y |
| Summer | | | | |
| 24 | Discoloration in pond | Y | Y | |
| 25 | Natural tree stress | Y | Y | |
| 26 | Vegetation | N | I | |
| 27 | Leachate discharge | Y | Y | |
| 28 | Vegetation along stream | N | N | |
| Autumn | | | | |
| 29 | Ground water springs | N | N | Y |
| 30 | Ground water springs | N | N | Y |
| 31 | Staining | I | N | N |
| 32 | Iron stain on creek | Y | N | N |
| 33 | Leachate spring | I | N | N |

FIGURE B.12
1980 SENSOR EVALUATION
(continued)

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Autumn - (cont'd) | | | | |
| 34 | Leachate spring | I | N | I |
| 35 | Leachate spring | I | N | I |
| 36 | Leachate spring | I | N | I |
| 37 | Leachate spring | I | N | N |
| 38 | Leachate spring | N | N | I |
| 39 | Ground water spring | N | N | Y |
| 40 | Vegetation | N | I | N |
| 41 | Ground cover | I | I | N |
| 42 | Leachate seep | N | N | N |
| 43 | Culvert discharge | N | N | I |

Y - feature identified
N - feature not identified
I - inconclusive or indistinct

## 6. CONCLUSIONS

Physical setting is a major factor in the utility and assessment of remote sensing techniques at Whitby.

Interpretation of archival photography shows the pre-landfill geology and ground water movement. By inserting the landfill into this setting, an interpreter can identify accurately the probable leachate seepage along the Lynde Creek valley and downstream of the landfilled drainage channel.

Heavy tree growth covers the leachate discharge areas. Therefore, vegetation effects are major indicators of landfill impact. Vegetation also obscures actual seepage areas and minor vegetation impact that does not affect tree top cover.

Colour infrared summer photography clearly illustrated the main leachate impact area and affected vegetation is easily identified. Despite the heavy ground staining along the valley, colour photography only partly identified the seepage during leafless conditions. However, colour photography identified small seepage areas not visible on the colour infrared.

April thermography was very useful in confirming the direction of leachate seepage across the alluvial plain detected on the colour infrared photography. However, the leachate springs are masked by coniferous trees along the slope.

No individual sensor recorded all leachate seepage areas.

## 7. IMAGERY USED AT THE WHITBY SITE

### 7.1 Archival

Archival photographs used at this site are:

| Year | Scale | Photo Number | Source |
|---|---|---|---|
| 1954 | 1:15840 | 4343-20 # 124-125 | M.N.R. |
| 1964 | 1:20000 | A18588 # 164-165 | N.A.P.L. |
| 1971 | 1:15840 | 4339-33 # 33-44 | M.N.R. |
| 1978 | 1:10000 | 4365-49 # 453-454 | M.N.R. |

### 7.2 1980 Imagery

Figure B.4 shows the area covered by the 1980 imagery. Scales, date and target photographs are given for each imagery set.

### 7.3 Sources

A complete set of imagery is available for viewing at the following offices of the:

Solid Waste Unit

Waste Management Branch
Ontario Ministry of the Environment
4375 Chesswood Drive
Downsview, Ontario
M3J 2C2

Central Region

Ontario Ministry of the Environment
Suite 700
160 Ferrand Drive
Don Mills, Ontario
M3C 3C3

Copies of imagery may be obtaned from:

1980 imagery - Contact Ministry of the Environment Offices.

Archival:

N.A.P.L.: National Air Photo Library
Energy Mines and Resources
615 Booth Street
Ottawa, Ontario
K1A 0E9
Telephone: (613) 995-4560

M.N.R. Public Service Centre
Ontario Ministry of Natural Resources
Whitney Block
Queen's Park
Toronto, Ontario
M7A 1W3
Telephone: (416) 965-1123

# Appendix C
# Oakville site

Remote Sensing Techniques &
Waste Management Assessments

# 1. INTRODUCTION

The Oakville landfill site is located 8 km northwest of the City of Oakville, east of Oakville Creek (Figure C.1). It is one of six southern Ontario landfills used in the study "Remote Sensing Techniques and Waste Management Assessment", prepared for the Ontario Ministry of the Environment. The purpose of the study is to evaluate specific remote sensing techniques for application to landfill monitoring and identification.

Colour and colour infrared aerial photography and thermography was acquired during 1980. This imagery, along with archival photography, was interpreted for application in monitoring and identifying existing landfill sites. A summary of the results, comparative evaluation of techniques and final study conclusions are presented in Volume 1 of this report.

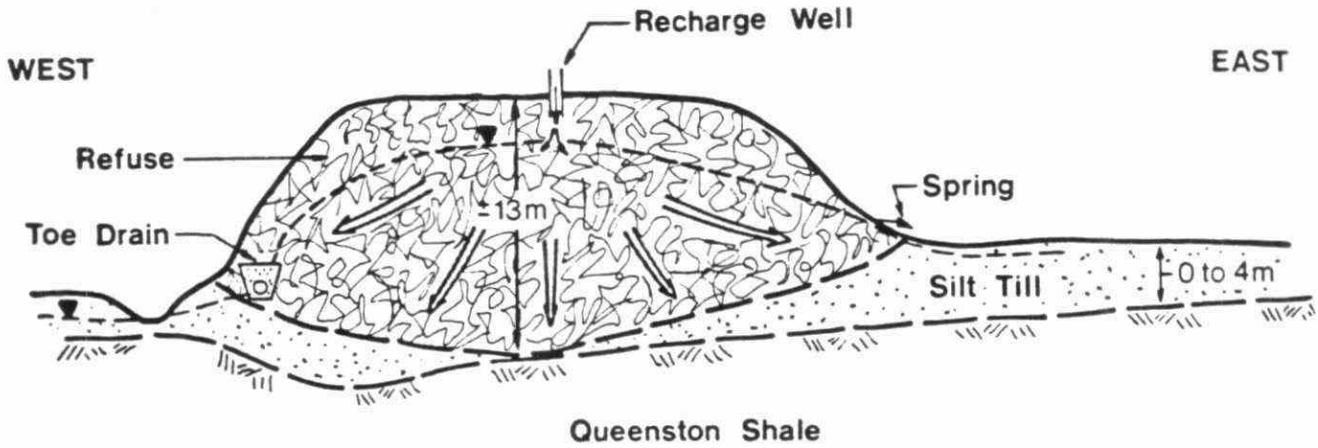
This appendix contains the detailed results for the Oakville site only. The appendix is one of six similar appendices comprising Volume 2. Together they provide all the detailed observations and data accumulated during this study. Each appendix is designed to be used separately with Volume 1, (the general text) if desired.

## 2. BACKGROUND

### 2.1 Physical Setting

The Oakville landfill site is built on a gently rolling till plain, underlain by Queenston shale at shallow depths (Figures C.2, C.3). The rectangular refuse mound rises about 10± m above the surrounding area (sketch below). The site is drained by two branches of a tributary of Oakville Creek - the streams flow along the perimeter of the site.

Schematic Cross Section of Oakville Landfill

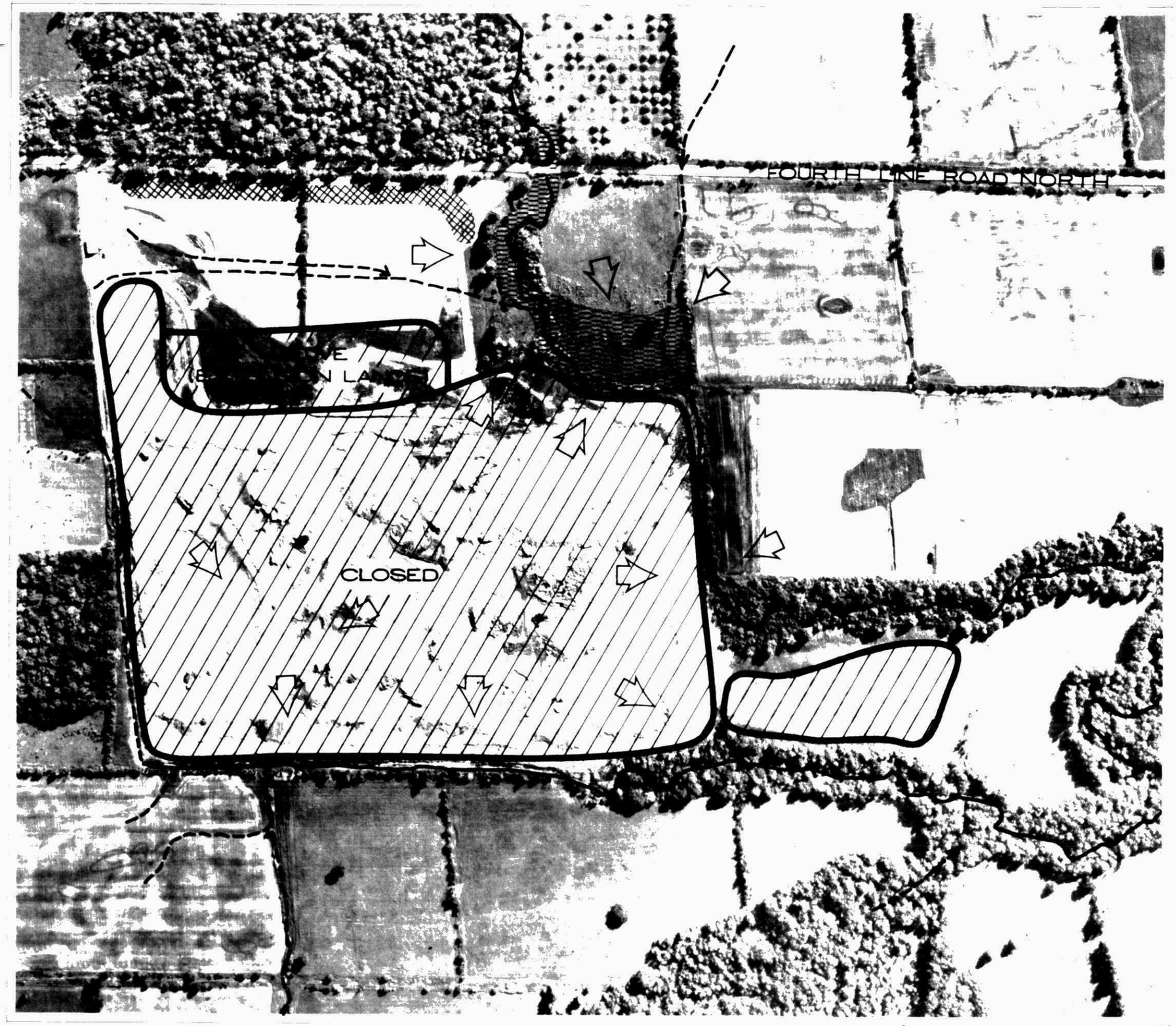



Subsoil investigations and detailed hydrogeological studies carried out for the Regional Municipality of Halton during the period 1979 to 1980 provide valuable data on the physical setting of this landfill.

The garbage has been placed over a compact to dense silt till, that has been excavated to shale bedrock in some areas. The till is a maximum of only 4 m thick, and bedrock actually outcrops on surface (i.e. stream valleys south of main site) in some locations.

Ground water mounds within the landfill forcing leachate to flow both vertically into the bedrock and laterally to emanate as springs around the toe of the landfill.

PETERBOROUGH
Little Britain
Port Perry
Uxbridge
Millbrook
Keene
Port Hope
Cobourg
Grafton
Brighton
Bowmanville
OSHAWA
Whitby
Ajax
Pickering
Brooklin
Claremont
Oak Ridges
AURORA
NEWMARKET
Aurora
Schomberg
Tottenham
Beeton
Bradford
Holland Landing
Queensville
Mount Albert
Keswick
Sutton
Stroud
Barrie
Orillia
Lindsay
Peterborough
Cobourg
Port Hope
Bowmanville
Oshawa
Whitby
Ajax
Pickering
Markham
Richmond Hill
Vaughan
Woodbridge
Kleinburg
Maple
Bolton
Caledon East
Caledon
Orangeville
Brampton
Georgetown
Streetsville
Mississauga
Toronto
Milton
OAKVILLE
Oakville
Burlington
Waterdown
Hamilton
Grimsby
Lincoln
Smithville
Caledonia
Mount Hope
St Catharines
Niagara-on-the-Lake
Niagara Falls
North Tonawanda
Lewiston
Queenston
Virgil
Port Dalhousie
Welland
Fonthill
Wainfleet
Ridgeway
Fort Erie
Buffalo
Grand Island
Tonawanda
Hastings
Warkworth
Campbellcroft
Orono
Hampton
Tyrone
Enniskillen
Kendal
Baltimore
Cold Springs
Beaverton
Port Perry
Sunderland
Manilla
Oakwood
Reaboro
Omemee
Mount Pleasant
Janetville
Seagrave
Greenbank
Blackstock
Pontypool
Cannington
Carsaregs
Lake
Keene
Raglan
Norwood
Stoney Landing
Parkwood
Ballinafad
Bethesda
Willow Beach
Jackson Point
Roches Point
Udora
Leaskdale
Zephyr
Queensville
Holland Landing
Bradford
Beeton
Tottenham
Schomberg
Aurora
Newmarket
Whitchurch-Stouffville
Stouffville
Claremont
Brougham
Pickering
Ajax
Whitby
Oshawa
Bowmanville
Newcastle
Port Hope
Cobourg
Grafton
Colborne
Brighton
Trenton
Belleville
Napanee
Kingston
Gananoque
Brockville
Prescott
Ottawa
Pembroke
Renfrew
Arnprior
Carleton Place
Almonte
Perth
Smiths Falls
Brockville
Cornwall
Alexandria
Hawkesbury
Lachute
Montreal
Sherbrooke
Granby
Drummondville
Trois-Rivières
Shawinigan
Joliette
Repentigny
Laval
Montreal
Valleyfield
Huntingdon
Malone
Plattsburgh
Burlington
Rutland
Brattleboro
Keene
Concord
Manchester
Nashua
Lowell
Lawrence
Haverhill
Portland
Augusta
Bangor
Calais
Saint John
Moncton
Fredericton
Edmundston
Campbellton
Bathurst
Miramichi
Chatham
Newcastle
Dalhousie
Moncton
Sackville
Amherst
Truro
Halifax
Yarmouth
Digby
Annapolis Royal
Kentville
Windsor
Wolfville
Middleton
Bridgetown
Liverpool
Lunenburg
Mahone Bay
Chester
Shelburne
Barrington
Clark's Harbour
Cape Sable Island
Pubnico
Meteghan
Digby
Weymouth
Yarmouth
Shediac
Cape Tormentine
Summerside
Charlottetown
Pictou
New Glasgow
Antigonish
Port Hawkesbury
Sydney
Glace Bay
North Sydney
Baddeck
Whycocomagh
Inverness
Port Hood
Mabou
Judique
Port Hastings
Canso
Guysborough
Sherbrooke
Liscomb
Musquodoboit Harbour
Dartmouth
Halifax
Bedford
Sackville
Fall River
Waverley
Enfield
Elmsdale
Truro
Tatamagouche
Pugwash
Wallace
Amherst
Springhill
Parrsboro
Advocate Harbour
Five Islands
Maitland
Noel
Walton
Lantz
Brookfield
Milford
Shubenacadie
Stewiacke
Upper Stewiacke
Alton
Debert
Great Village
Londonderry




Ministry of the Environment
Ontario

# C·2 Physical setting

FILL AREA (NOVEMBER, 1980)

SHALLOW TILL PLAIN

FLOOD PLAIN

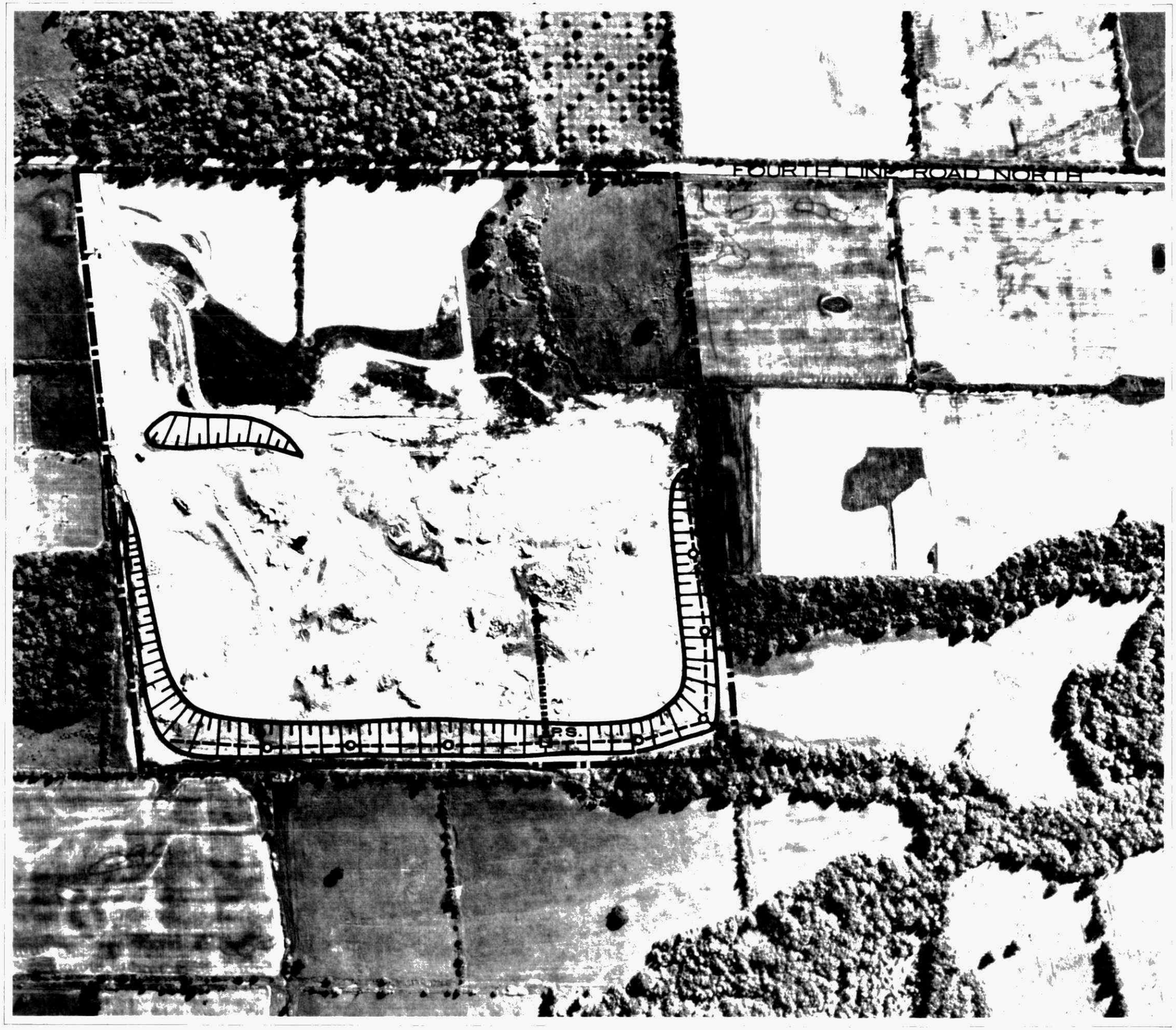
WATERCOURSES

PROBABLE SHALLOW GROUND WATER FLOW DIRECTION

BERM

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES




Ministry of the Environment
Ontario

# C-3 Site plan

PROPERTY BOUNDARY

LANDFILL LANDFORM SIDE SLOPES

LEACHATE COLLECTION SYSTEM

TOEDRAIN LEACHATE COLLECTOR

FORCEMAIN

P.S. PUMPING STATION

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

A leachate collection system, installed during the last few years is presently being expanded to intercept this toe seepage and recycle the leachate through a recharge well situated on the landfill.

## 2.2 Site History

In operation since 1960, the site was owned and operated by the Town of Oakville until 1974. At that time operations and ownership were assumed by the newly created Regional Municipality of Halton. Until 1977 the site was operated by regional forces and subsequently by private contractor.

A large proportion of wastes - in 1968 reported to be 80% of the site total - from auto and truck assembly plants in Oakville were routinely burned until 1973 with ashes dumped into ponded trenches for quenching. Some segregation of wastes was carried out, with paper and wood primarily being burned. Although burning was carried out infrequently after 1973, smoldering of refuse beneath the site cover was reported in 1974.

Earth cover for landfilling operations has been taken from trenches excavated periodically on site. These trenches varied in length from approximately 100 m to 300 m; in width 10-15 m; and in depth 5-10 m and were subsequently landfilled. Records of site operations and subsequent subsurface investigations indicate that excavations were discontinuous. In some cases these were located in close proximity to perimeter drainage works.

Prior to landfilling, a stream flowed through the southeast part of the site. During operations drainage patterns were altered frequently. In the latter part of the 60's the stream in the southeast was "squared off" to accomodate landfilling in the areas. Records show that a berm was constructed at the toe of the landfill adjacent the Creek. It is likely that this berm was intended to prevent the discharge of leachate to the diverted stream at the toe of the landfill and to prevent the flow of stream water into site excavations.

In 1969, the site was expanded by acquisition of lands to the north.

The first recorded evidence of leachate was in 1973. Two or three minor seeps were reported in the south area of the site and a pool of leachate was reported in the southwest corner where a berm was constructed to prevent leachate from draining to surface water. Minor leakage was reported near the top of this berm.

Reports of leachate outbreaks were recorded in 1974, 1975, 1976 and 1977. These were reported most frequently on the west and south slopes of the landfill. In 1974 ponded leachate was noted entering the surface drainage system.

In 1978 a toe drain leachate collection and recirculation system was installed on the west and south slopes of the site. Leachate drains by gravity to a pumping station where it is then pumped via a forcemain to a leachate recharge well in a central area of the site. Although the system was intended to intercept the toe discharge of leachate, the irregular and unpredictable base topography of the site was

lower in some places than the leachate collection piping. In these localized areas, leachate seepage continued and was not intercepted by the collectors.

Analysis of 1972 mapping indicates that in the vicinity of a major leachate spring on the south slope of the landfill, pre-landfill contours describe a swale beginning in a central area of the site and draining to a stream to the south. Coincidentally, the leachate recharge well was located at the head of this swale. Thus leachate collected at the perimeter of the site is recharged into the site and channeled via this swale to the leachate spring on the south slope. Investigations have been undertaken to correct this condition and remedial works designed. Investigations carried out on the existing leachate system indicate that leachate had been flowing under the toe drain collector and discharging to surface drainage works.

In 1978, 1979, and 1980 extensive work was carried out for site rehabilitation. A final cover application of 0.6-1.0 m was made and the entire site regraded and seeded. In the summer of 1980 operations were expanded to an area to the east of the site and west of Fourth Line Road.

## 3.0 METHODOLOGY

The prime objective of the study was to evaluate remote sensing techniques for thier applicability to waste management programs. Six sites were selected for the study and a program for acquisition of remote sensing data for the sites was developed.

Four remote sensing techniques were selected for this study:

i) colour aerial photography
ii) colour infrared aerial photography
iii) aerial thermography
iv) archival photography

Each sensor was expected to be capable of providing specific data on the condition of each site - in particular the discharge of leachate (colour aerial photography and aerial thermography). The sites selected represented a range of differing hydrogeological conditions, with a known history of surface discharge of leachate, and with various stages of site operation and site rehabilitation.

The selected sites were:

Cobourg Landfill Site
Whitby Landfill Site
Oakville Landfill Site
Bayview Park Landfill Site (in Burlington)
Burlington Landfill Site
Upper Ottawa Street Landfill Site -
(in Hamilton)

The program for evaluation of sensors comprised initially the acquisition and review of hydrogeological assessments made

for the site through previous studies. In addition, to assist in providing an understanding of site history and past operations, archival photography was obtained dating back to 1954 and taken at intervals ranging from 5 to 7 years. To further assist in constructing a site development history, a review of Ministry files for the site was made. Observations of site operations and leachate discharge were reported and give insight on the development of leachate mounding and on operational procedures which have conributed to present site conditions.

The schedule for remote sensing data acquisition was:

| Sensor | Flight Date | Field Reconnaissance |
|---|---|---|
| colour photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 5 May 1980<br>6 August 1980<br>18 November 1980 |
| colour infrared photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 5 May 1980<br>6 August 1980<br>18 November 1980 |
| thermography | 4 March 1980<br>17 April 1980<br>26 November 1980 | 5 May 1980<br>6 August 1980<br>18 November 1980 |

Photography scale was changed from 1:8000 for March and April flights to 1:6000 for July and November flights. Average

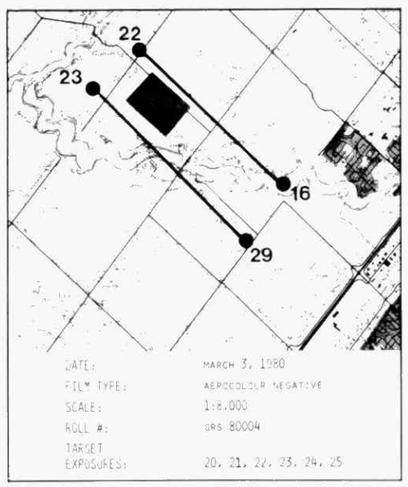
flying altitude for thermography was 1050 m, giving an approximate scale of 1:14000. Data acquisition details are given on Figure C.4.

After each flight, photography and imagery were examined and preliminary interpretations made. Detailed field reconnaissance was made to confirm interpretations and to identify any features undetected on the sensor data. Photography and imagery for each flight were annotated and annotations for subsequent flights compared so that assessment of the relative effectiveness of sensors under varying seasonal conditions would be made.

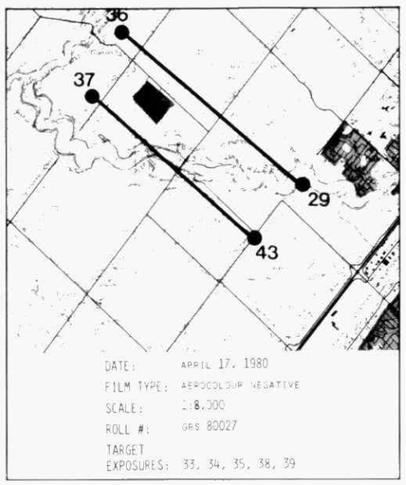
Following completion of all data acquisition, interpretations and field work, comparative assessments of data with respect to season, sensor type, and type and extent of features sensed were made. Site features detectable in the field were noted and compared to those interpreted from photography and imagery. These records and interpretations were used as a basis for determining the effectiveness of each technique.

The relative merits of the various sensors in satisfying the study objective and taking into account relative costs of data acquisition were then assessed.

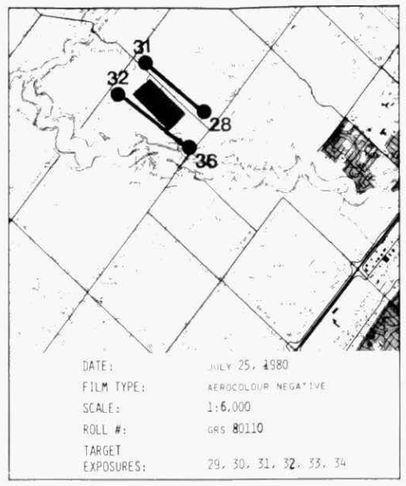
TRUE COLOUR



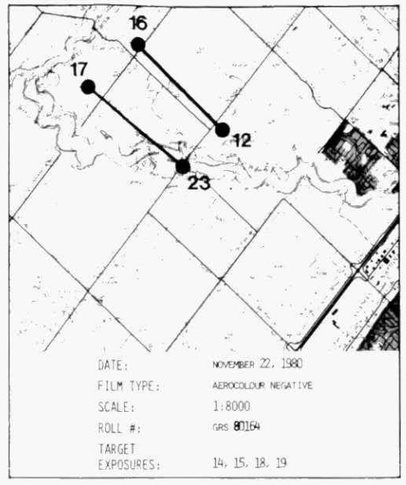

DATE: MARCH 3, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80004
TARGET EXPOSURES: 20, 21, 22, 23, 24, 25




DATE: APRIL 17, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80027
TARGET EXPOSURES: 33, 34, 35, 38, 39

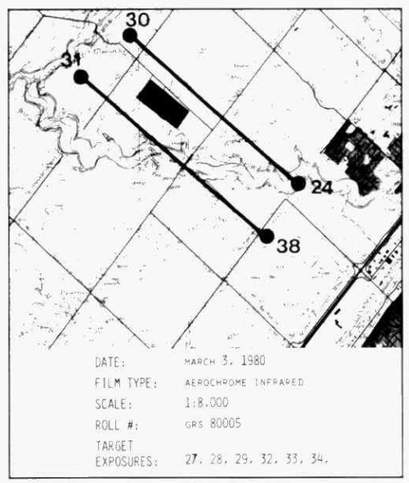



DATE: JULY 25, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:6,000
ROLL #: GRS 80110
TARGET EXPOSURES: 29, 30, 31, 32, 33, 34

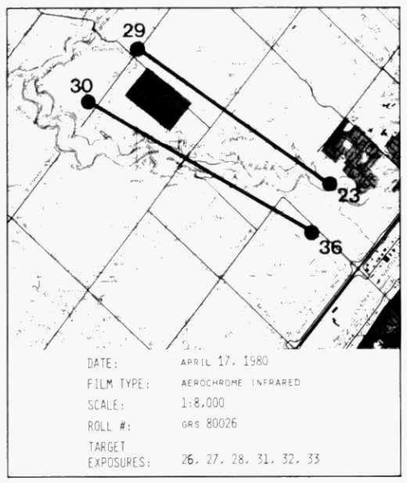



DATE: NOVEMBER 22, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8000
ROLL #: GRS 80164
TARGET EXPOSURES: 14, 15, 18, 19

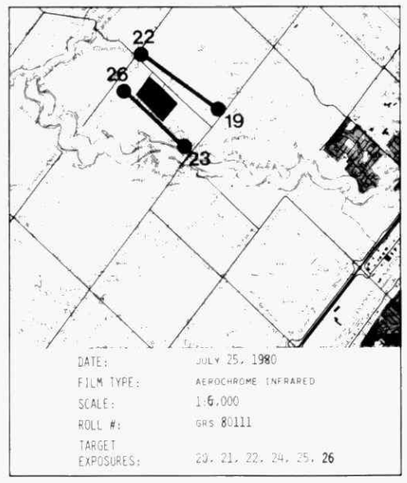
COLOUR INFRARED



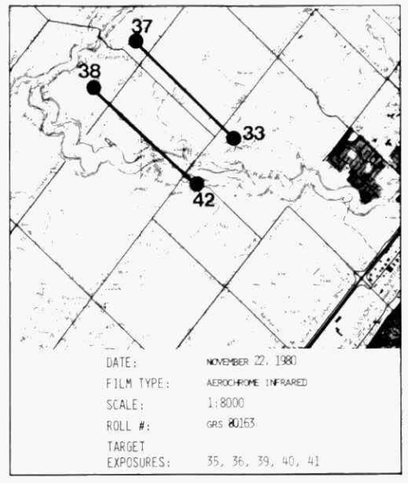

DATE: MARCH 3, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80005
TARGET EXPOSURES: 27, 28, 29, 32, 33, 34,




DATE: APRIL 17, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80026
TARGET EXPOSURES: 26, 27, 28, 31, 32, 33

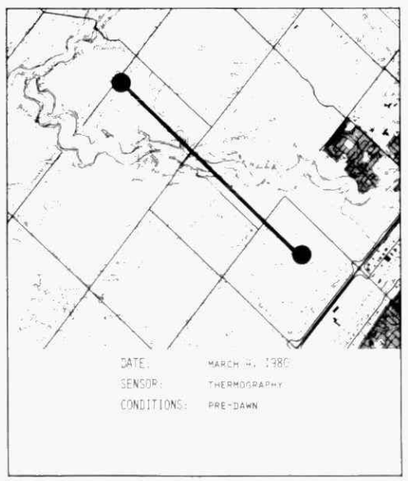



DATE: JULY 25, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:6,000
ROLL #: GRS 80111
TARGET EXPOSURES: 20, 21, 22, 24, 25, 26

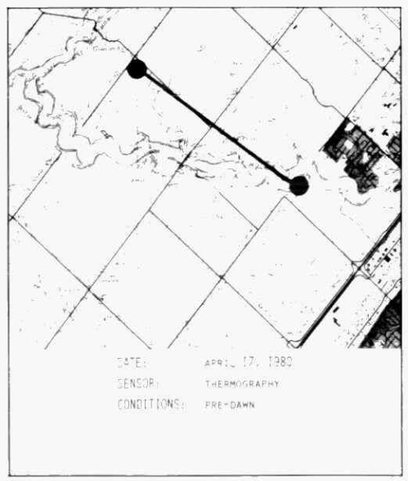



DATE: NOVEMBER 22, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8000
ROLL #: GRS 80163
TARGET EXPOSURES: 35, 36, 39, 40, 41

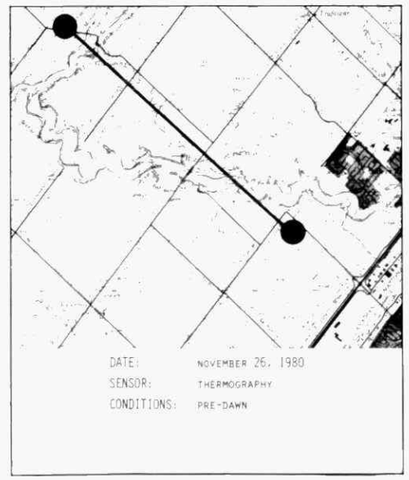
THERMOGRAPHY



DATE: MARCH 14, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN



DATE: APRIL 17, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN



DATE: NOVEMBER 26, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN

LATE WINTER | SPRING | SUMMER | AUTUMN

Ministry of the Environment
Ontario

# Oakville site

# C·4 Data Acquisition (1980)

0 2 kilometres

## Remote Sensing Techniques & Waste Management Assessment


**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

that this area is landfilled. The main site area has expanded slightly, and the refuse mound is much higher. The leachate collection system is visible.

## 4.2 Late Winter Data 1980

### 4.2.1 Sensing Conditions

The early March imagery was intended to study winter conditions. However, snowfall was abnormally low during the mild 1979/1980 winter and at the time of photography, snow accumulation was generally confined to protected hollows and perimeter ditches. As a result, there was not the continuous white background on the photography to enhance leachate caused gaps and staining. However, since soil and water surfaces were frozen, thermal contrast was still clear. Weather data prior to acquisition are listed in Figure C.6.

### 4.2.2 Diagnostic Features

Figure C.7 shows the locations of imagery observations made at the Oakville site. These observations were made on the colour, colour infrared and thermography for all of the seasonal imagery.

a) Colour

In general, three indicators of leachate seepage are identified on the colour photography:

i) a seepage zone, indicated by dark soil tone;

## 4. STUDY RESULTS

### 4.1 Archival Photography

The panchromatic archival photography illustrates the landfill development and associated changes in the landscape from 1954 (prior to landfilling) to 1978. These data, particularly surface drainage changes, are plotted on Figure C.5. Significant details observed in the various years are outlined below.

Prior to landfilling (1954), the site was gently rolling farmland, drained by several intermittent drainage channels. The eastern branch of the tributary meanders through a flood plain adjacent to the future site.

By 1959, initial landfilling activity has begun. An area of approximately 60 m by 180 m has been disturbed and piles of fill or refuse are visible on the site.

The 1965 photography indicates an active landfill site. A trench excavated at the southeast end of the site (A, Figure C.5) drains into the adjacent stream. Mounds of refuse and/or fill are clearly visible. In 1972, landfilling has expanded almost to the final boundary. Drainage along the western perimeters has been rerouted via a perimeter ditch. The eastern stream has also been rerouted by ditching and by encroachment of the landfill over the old flood plain. A remnant of the westerly stream (B, Figure C.5), carries site runoff (and probably leachate) into the stream.

The 1978 photographs indicate that landfilling may have occurred between 1972 and 1978, southeast of the site. The surface has been disturbed, although there is no significant visible topographic change. Field studies indicate

that this area is landfilled. The main site area has expanded slightly, and the refuse mound is much higher. The leachate collection system is visible.

## 4.2 Late Winter Data 1980

### 4.2.1 Sensing Conditions

The early March imagery was intended to study winter conditions. However, snowfall was abnormally low during the mild 1979/1980 winter and at the time of photography, snow accumulation was generally confined to protected hollows and perimeter ditches. As a result, there was not the continuous white background on the photography to enhance leachate caused gaps and staining. However, since soil and water surfaces were frozen, thermal contrast was still clear. Weather data prior to acquisition are listed in Figure C.6.

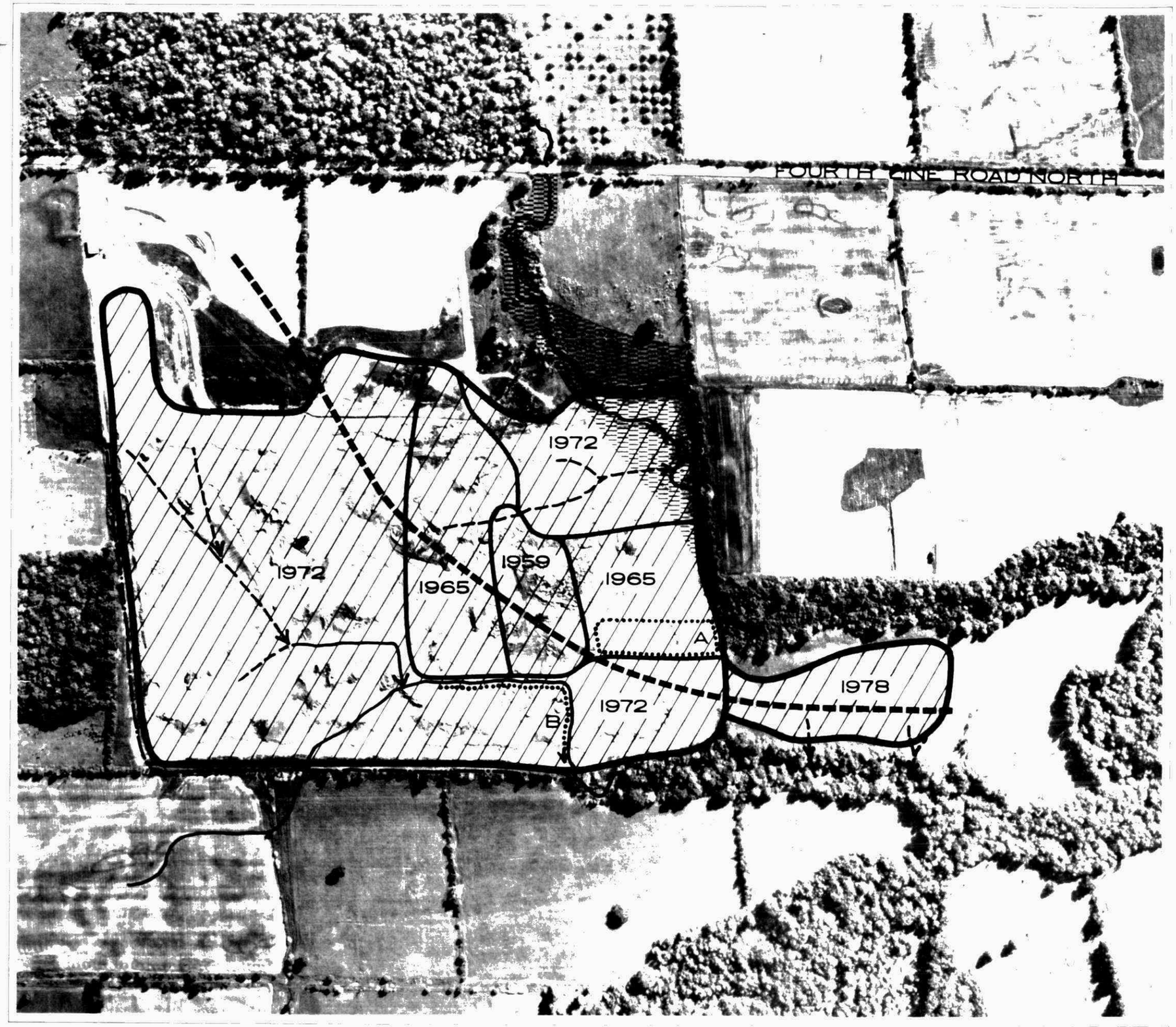
### 4.2.2 Diagnostic Features

Figure C.7 shows the locations of imagery observations made at the Oakville site. These observations were made on the colour, colour infrared and thermography for all of the seasonal imagery.

a) Colour

In general, three indicators of leachate seepage are identified on the colour photography:

i) a seepage zone, indicated by dark soil tone;




Ministry of the Environment
Ontario

# C·5 Archival photography

PRE-LANDFILL CONDITIONS (1954)

DRAINAGE

SURFACE DRAINAGE DIVIDE

FLOOD PLAIN

LANDFILL CONDITIONS (1959 TO 1978)

DRAINAGE CHANGES (1972)

A TEMPORARY CONDITION

EXTENT OF LANDFILL AREA (WITH YEAR)

NOTE PHOTOGRAPHY FROM 1954, 1959, 1965, 1972, 1978.

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

FIGURE C.6

WEATHER DATA[1]: OAKVILLE LANDFILL

| DATE | TEMPERATURE (°C) | | | Precipitation[2] |
|---|---|---|---|---|
| | Maximum | Minimum | Mean | |
| **Late Winter** | | | | |
| February 27 | - 1.5 | - 8.0 | - 4.5 | |
| 28 | - 8.0 | -15.5 | -11.5 | |
| 29 | -12.5 | -21.5 | -17.0 | |
| March 1 | -11.0 | -20.5 | -15.0 | |
| 2 | - 5.0 | -20.5 | -13.0 | |
| 3 | .5 | -13.5 | - 7.0 | |
| 4 | 4.0 | - 5.0 | 0.0 | Tr (S) |
| **Spring** | | | | |
| April 12 | 12.0 | 3.0 | 7.0 | 4.0 (R) |
| 13 | 12.0 | 1.0 | 6.0 | Tr (R) |
| 14 | 9.0 | 1.0 | 5.0 | 15.0 (R) |
| 15 | 4.0 | 2.0 | 3.0 | |
| 16 | 3.5 | - 4.0 | 0.0 | |
| 17 | 11.0 | - 4.5 | 3.5 | |
| **Summer** | | | | |
| July 20 | 26.5 | 19.5 | 22.5 | 1.4 (R) |
| 21 | 31.5 | 19.0 | 25.0 | 2.5 (R) |
| 22 | 22.0 | 20.0 | 21.0 | 6.9 (R) |
| 23 | 25.5 | 16.5 | 21.0 | |
| 24 | 25.5 | 13.5 | 19.5 | |
| 25 | 29.5 | 17.0 | 23.0 | |
| **Autumn** | | | | |
| November 16 | 1.0 | - .5 | 1.0 | |
| 17 | 2.0 | - 7.5 | - 3.0 | |
| 18 | 2.0 | - 3.5 | - 1.0 | |
| 19 | 2.5 | - 2.5 | 0 | |
| 20 | 7.0 | - 1.5 | 3.0 | |
| 21 | 6.5 | 3.0 | 5.0 | |
| 22 | 6.0 | - 1.0 | 2.5 | |
| 23 | 7.5 | 3.0 | 2.0 | .8 (R) |
| 24 | 7.5 | 4.5 | 6.0 | 2.8 (S) |
| 25 | 2.5 | - 1.0 | .5 | |
| 26 | 4.0 | - 5.0 | - .5 | |
| 27 | 4.0 | - 4.0 | 0.0 | 6.0 (R) (Tr (S)) |

1. Source, Oakville weather station
2. (R) rain in mm
   (S) snow in cm
   (Tr) trace of precipitation

ii) faint reddish staining of snow along the perimeter ditch;

iii) snow-filled gullies starting mid-slope of the landfill face.

All of the features are small and often indistinct. Two represent active seepage while the third illustrates former seepage. Field verification is necessary to confirm leachate springs.

Indicators are concentrated around the site perimeter, particularly along the western side, where there is less landfill activity.

The following observation stations located on Figure C.7 refer to the colour aerial photography.

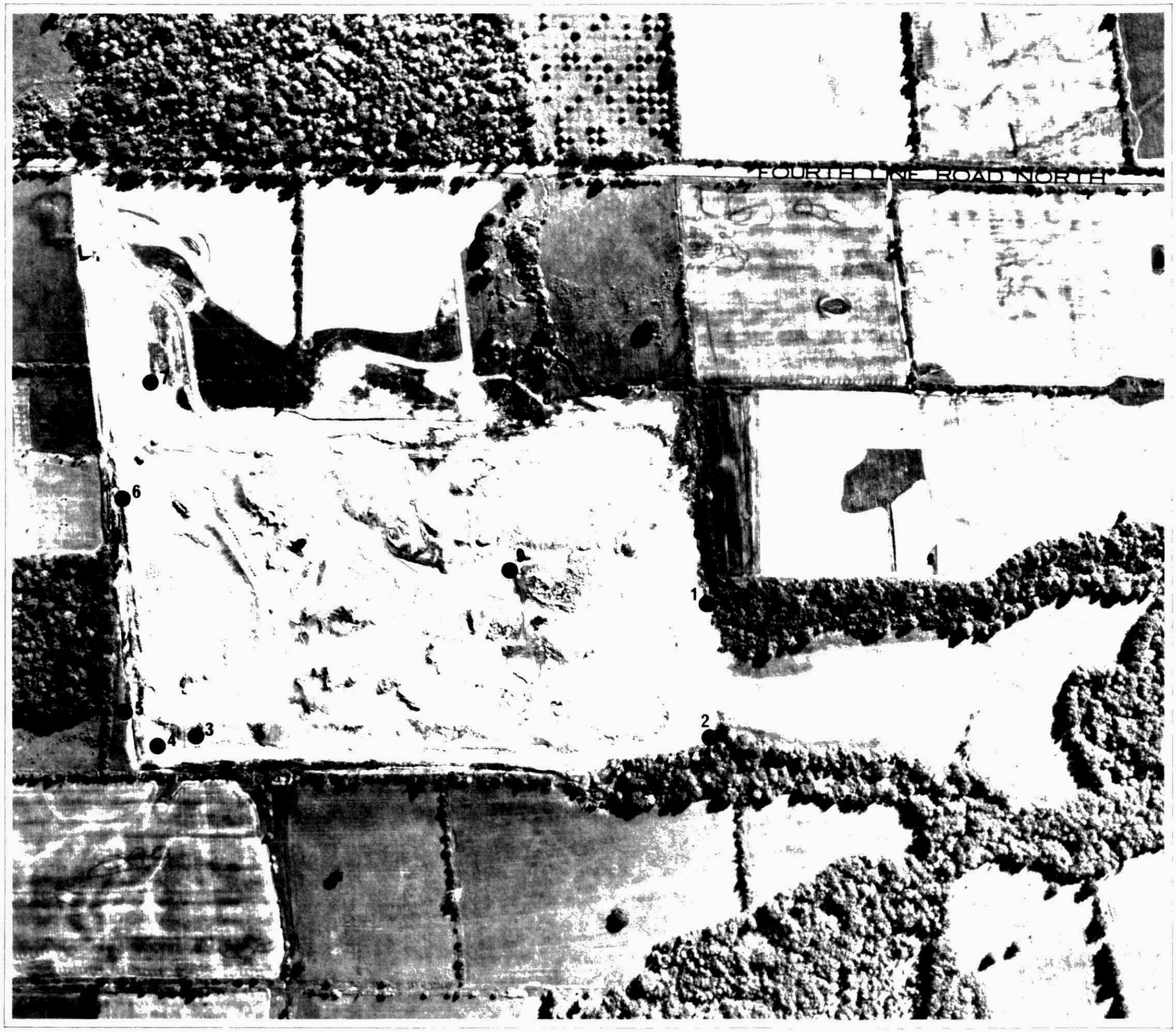
Station 2: Snow-filled gully begins halfway down the landfill slope; may mark seasonal leachate spring.

Station 3: Line of darker toned soil extends about 40± m; may identify leachate seepage.

Station 4: Snow-filled gully at north end of toe drain collector may mark seasonal leachate seep.

Stations 5 & 6: Faint reddish staining of snow along perimeter ditch.

Station 9: Recharge well.




Ministry of the Environment
Ontario

# C·7 Late winter data
(March 1980)

●4 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80004-20,25
COLOUR INFRARED PRINT
– GRS80005-33

0 500 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

b) Colour Infrared

Fewer leachate indicators were observed on the colour infrared photography than on the colour. The faint reddish staining is not visible at all.

The following observation stations located on Figure C.7 refer to the colour infrared aerial photography.

Station 3: Linear dark soil tone on landfill face - seepage zone.

Station 4: Snow-filled gully may locate seasonal leachate spring.

Station 9: Recharge well.

c) Thermography

Leachate outbreaks at the Oakville landfill site are characterized by the following signatures:

Station 1: Warm thermal anomaly; poorly defined.

Stations 2, 4, 5, 6, 8: Very bright, distinct anomalies identify apparent leachate seepage points. Station 8 is unique in that the crispness of the thermal anomaly is deteriorated, suggesting that there is gradual cooling at this point. Station 6 is a line of anomalies, extending several metres along the ditch.

Station 7: Ponding has a bright thermal signature similar to that of seepage. However, it covers a larger area and sometimes has an irregular shape. Leachate and non-leachate ponding cannot be distinguished.

Station 9: This bright thermal anomaly is the leachate recharge well.

## 4.3 Spring Data 1980

### 4.3.1 Sensing Conditions

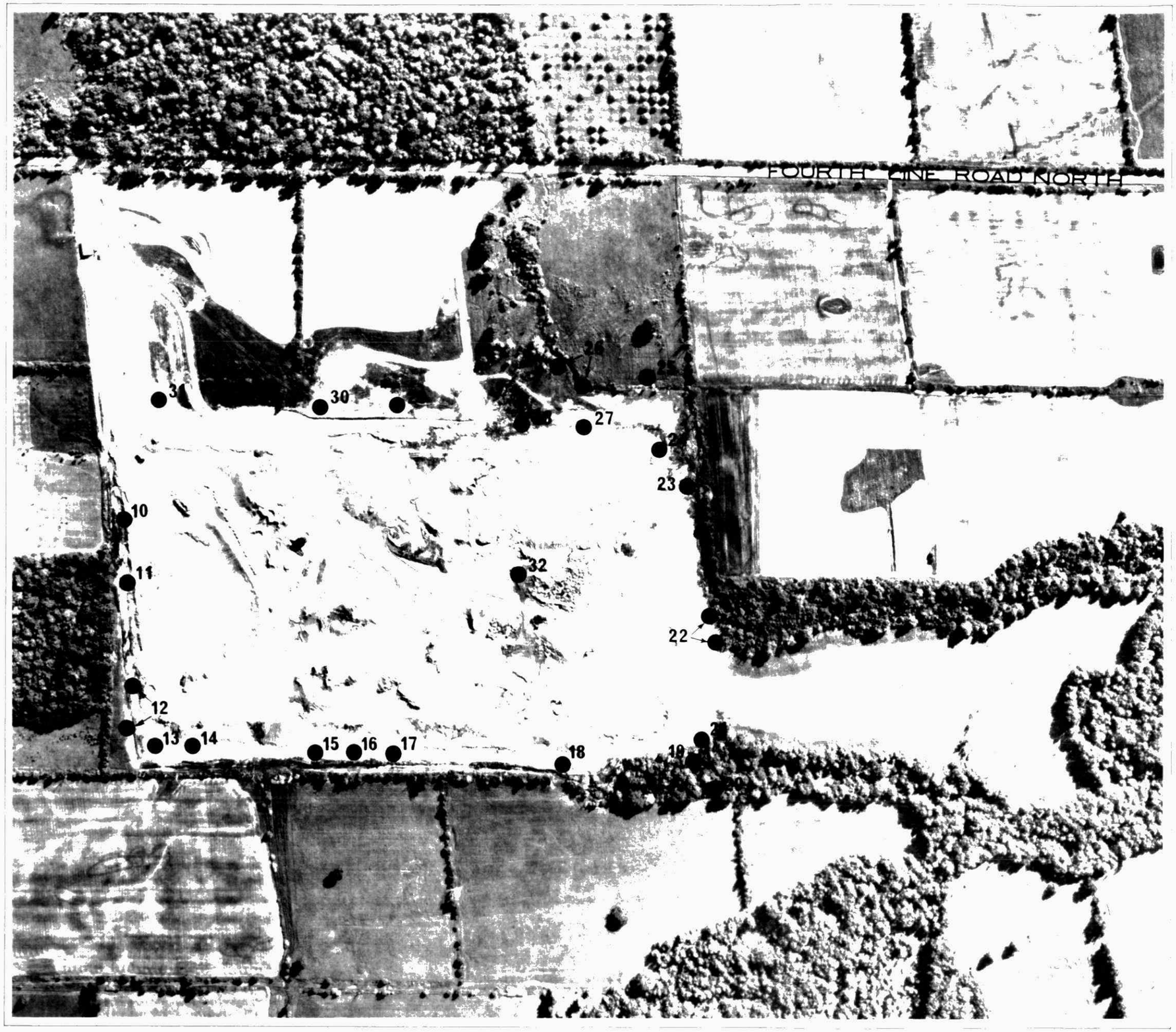
The 17 April 1980 imagery exhibits typical spring conditions: leaf-free deciduous trees, snow-free ground surface and high water table conditions. The lower temperature contrasts make the thermography appear "flatter" than in March, while high soil moisture increased background thermal information. Weather conditions prior to 17 April 1980 are listed in Figure C.6.

### 4.3.2 Diagnostic Features

Field and imagery observations are located on Figure C.8. Data are concentrated around the site perimeter. Duplicate observations are recorded at several stations.

a) Colour

Surface staining identifies several possible leachate seeps around the site perimeter. A dark stain on the landfill face coincides with a snow-filled gully visible on March photo-




Ministry of the Environment
Ontario

# C·8 Spring data
(April 1980)

●18 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (R80CC)
COLOUR PRINT
– GRS80027-34,38
COLOUR INFRARED PRINT
– GRS80026-31

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

graphy, both conditions indicative of a leachate seep. The remaining surface staining is a very faint reddish-brown colour.

Ponded surface runoff has a red-brown tone derived from the soil cover used at the site. This masks leachate staining or seepage in this area.

The following observation stations are found on Figure C.8.

Stations 10, 11, 12, 15, 16, 17: Faint reddish-brown staining on soil in the ditch or near the landfill toe suggests several small scattered seeps.

Station 13: Dark staining on grassed area of landfill face coincides with Station 4 and probably indicates leachate seep.

Station 14: Line of darker surface tone visible, with darker zones now leading from line down slope (incipient leachate outbreak).

Station 18: Faint reddish staining visible at pump house.

Stations 27 to 31: Reddish-brown ponded water is predominantly surface runoff coloured by sediment from soil cover; leachate seepage or leachate contaminated pools cannot be distinguished from surface runoff.

b) Colour Infrared

The dark leachate staining is visible on the colour infrared imagery. The reddish-brown staining - which appears green against the blue soil tone - is only detected at one station.

Early vegetation growth (red tone) is just visible on the landfill face near a surface runoff pool. This may indicate leachate seepage (warmth and moisture encourage growth) or an undisturbed area of the landfill.

The following observation stations are found on Figure C.8.

Station 10: Reddish-brown surface staining appears as faint greenish tone. Indistinct observation.

Station 13: Black tone (dark staining) indicates leachate seepage; coincides with snow filled gully.

Station 14: Incipient seepage (dark tone) is just visible.

Station 29: Scattered early vegetation growth (red tone) on landfill face - response to leachate seepage or hardy pioneer vegetation.

Stations 27 to 31: Sediment laden runoff has blue tone.

c) Thermography

Leachate outbreaks at the Oakville landfill are characterized by the following signatures:

Stations 10, 22, 26: Leachate seepage points on the thermography appear much warmer (brighter) than their surroundings.

The point-sources are not as distinct and sharp as during drier seasons. At Station 26 leachate is seeping into a stream; the thermal signature is bright and appears to follow the stream channel.

Stations 29, 30, 31: Ponding appears on the April imagery as areas of warm thermal anomalies. During this wet season, distinguishing between natural ponding and leachate ponding is not possible.

Station 29, 30, 31: Thermal anomalies attributed to wet soil areas.

Station 32: Anomaly produced by leachate recharge well.

d) Field Visit

Numerous leachate seeps and springs were identified during the 5 May 1980 field visit. Several of these outbreaks - while visible on the ground - were not detected on the various imagery.

Detailed observations:

Stations 10, 11: A series of leachate seeps at toe of landfill occur along lower landfill slope.

Station 12: Small leachate springs entering stream at toe of fill; small bubbles in stream.

Station 13: Leachate spring from north end of toe drain; strong odor; red staining on grass.

Station 14: No leachate staining or seepage is visible along the slope to coincide with imagery observations.

Stations 14 to 18: Many very small leachate seeps occur all along the landfill toe from the end of the toe drain to the pump house; many more seeps observed in field than on imagery; most seeps are less than .3 to .1 m wide.

Station 20: Natural ground water seepage on west side of stream bank.

Station 19: Minor leachate seepage at toe of landfill.

Station 21: Small leachate seep below toe drain; coincides with snow-filled gully on March colour photography.

Station 22: Two leachate springs occur: (i) small spring from mid slope, about 15 m from stream, on west ridge; (ii) major spring at base of slope, discharging black leachate into stream; 10± gpm flow; spring about 1 m above stream.

Station 23: Leachate seepage at toe of fill.

Station 24: Small leachate rivulet (intermittent ponding) along southeast side of landfill - only about 30 m long, .1 to .3 m wide; - small pool leachate (?), bubbling vigorously at crest of stream wall.

Station 25: Ponded water; - some leachate contamination possible.

## 4.4 Summer Data 1980

### 4.4.1 Sensing Conditions

Summer photography at 1:6,000 scale was obtained on 25 July 1980. Typical summer conditions - full vegetation cover and

slight stress in ground cover due to summer drought - are visible. Weather conditions prior to the 25 July 1980 are listed in Figure C.6.

The main site is closing down during this period and final soil cover is being applied. Along the east side of the landfill, the expansion lands are being prepared for future landfilling. This activity affects leachate detection on the imagery.

### 4.4.2 Diagnostic Features

Features observed on the photographs and in the field are located on Figure C.9. Note the duplication between colour and colour infrared imagery.

a) Colour

Colour photography detected a new leachate outbreak on the southwest face of the landfill (Station 35). The dark leachate has killed grass on the slope and cattails in the perimeter ditch (Figure C.10). The seepage stain and dead vegetation are very clear on the imagery. The seep at the end of the toe drain, now appears as a patch of dead grass. Both seeps are active, and appear to emanate from the "incipient seepage" line seen on earlier photography (Station 14, Figure C.8).

Faint to dark reddish-brown staining around the landfill toe indicates probable leachate seepage. The red-brown coloured pools on and around the main site are probably mainly surface water with some leachate seepage.

The following observations are related to the stations shown on Figure C.9.

Station 33: Natural gaps in grass cover (white to grey tone).

Station 34: Dead grass and staining corresponds to gully and staining on previous photography.

Station 35: Dark reddish staining with dead vegetation (grey) visible around stain (dead grass) and in ditch (dead cattails); new leachate seep elevation same as the previously observed incipient seepage zone.

Station 36: Very faint dark red-brown tones occur along toe of slope.

Station 37: Faint red-brown staining at corner of pump house.

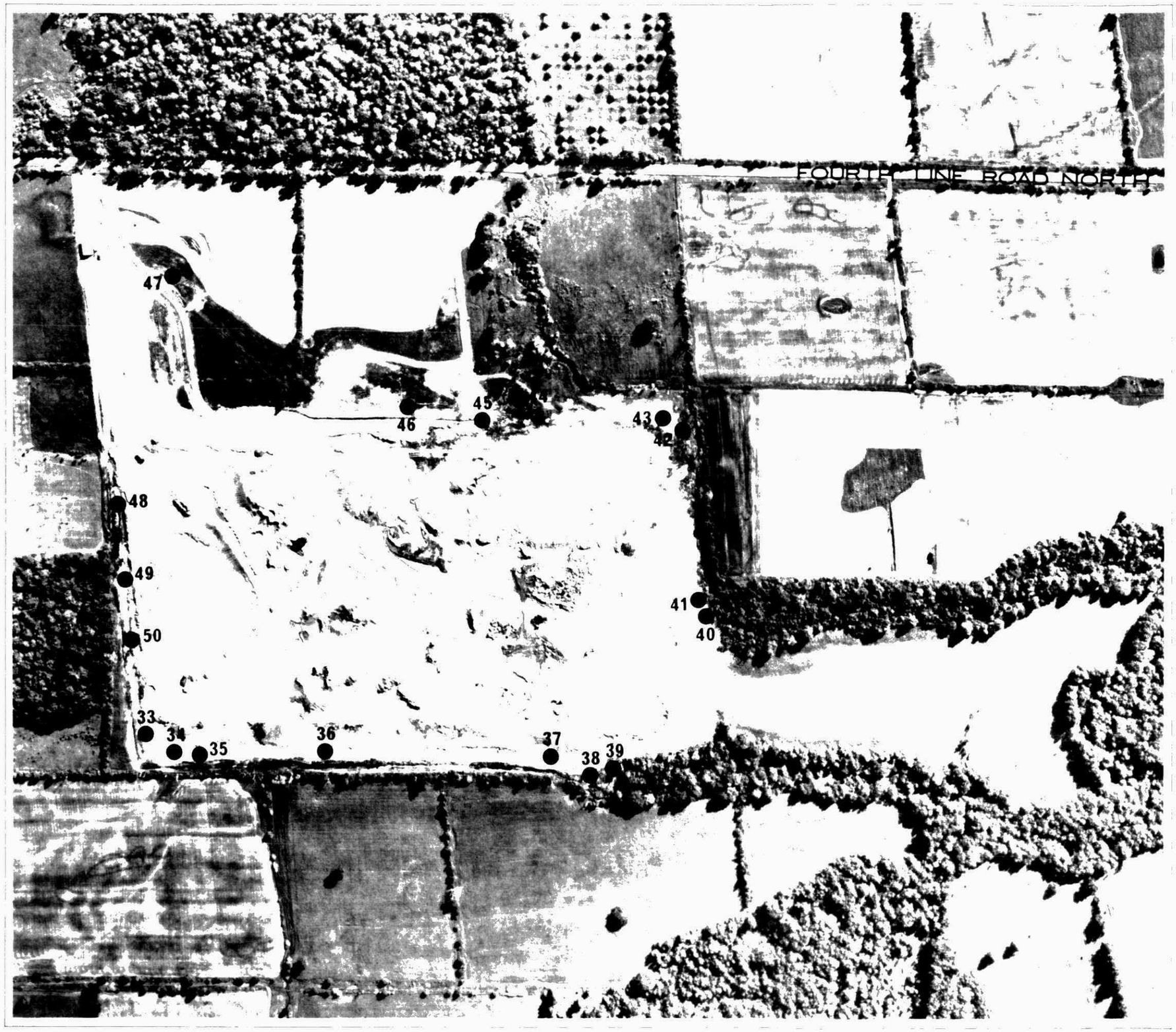
Station 38: Dead tree; grey tone and open crown.

Station 41: Trench excavated into landfill to investigate toe drain.

Station 43: Linear (stream-like) dark red-brown staining.

Stations 45, 46: Dark reddish staining or lines of seepage occur at toe of landfill.

Station 50: Seepage (dark soil tone) and reddish staining near toe of slope.




Ministry of the Environment
Ontario

# C·9 Summer data

( July 1980 )

●47 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS - 6000
COLOUR PRINT - GRS8[illegible]-33
COLOUR INFRARED PRINT - GRS8[illegible]-25

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Station 47: Largest of several red-brown pools around landfill; no means to distinguish simple surface runoff pools from pools with leachate seepage.

b) Colour Infrared

The staining and vegetation kills caused by the new leachate seep are very distinct on the colour infrared. The former large seep appears as a yellow-grey tone. Other red-brown leachate staining is not detected.

Vegetation stress, (positive and negative) observed in ground cover around the landfill toe is inconclusive. Much of this stress, and stress in treed areas adjacent to the site, may be natural.

Observations located on Figure C.9 are described as follows:

Station 33: White-grey tone indicates bare soil gaps in vegetation.

Station 34: Leachate killed grass; compared to Station 33 where grey to white tone is bare soil, not caused by leachate.

Station 35: Leachate stain is visible as black stain surrounded by dead grass (yellow grey); dead vegetation along ditch below stain. Stain is more visible on colour infrared than colour photography.

Stations 35 to 33: Grass shows same vegetation stress (mottled pink vs. healthy red) as nearby crops and fallow; mostly due to summer drought.

Station 37: Healthy (red tone) vegetation growing on east side of pump house; this is up-slope from the leachate stain observed on colour photography; stain appears as faint yellow-grey tone on this photography.

Station 36 to 37: Minor stress appears to be occurring in some vegetation along the ditch opposite the landfill (mixture of healthy red to pink tones); stress may be landfill related but most is probably natural.

Station 38: Dead tree - appears as grey, with open crown.

Station 39: Ground cover is stressed (grey-green tone); not visible on colour.

Stations 40 to 42: Slightly stressed (pink tone) mixed with vigorous (red tone) vegetation is visible along the stream bank beside the landfill.

Station 44: Area of healthy (red) ground cover amongst stressed vegetation, that is more typical of ground cover; appears as dark green vegetation on colour photography. Possible seepage or ponding causing healthier growth.

c) Thermography

Thermographic coverage for the summer data acquisition period was unavailable due to the emergency use of the thermal line-scanner for forest fire mapping. However, thermographic investigation of leachate outbreaks during the summer season is not considered to be very effective; consequently, the loss of summer data was not of serious consequence to the research program.

d) Field Observation

Active leachate seepage and springs around the landfill toe were confirmed during the 6 August 1980 field visit.

Station 33: Natural gaps in grass cover.

Station 34: Grass kill about 1 m square immediately up-slope of the toe drain end; a clear leachate spring (.25 gpm) flows from the base of the grass kill, above the toe drain collector alignment; former seepage here was at toe drain.

Station 35: Dark reddish toned leachate from line of seepage is staining and killing vegetation in 2 m band down slope; cattails killed where seepage enters ditch at base of slope; strong leachate odor.

Note: Vegetation is killed only under seepage and as "halo" about 30 cm wide around seepage. See Figure C.10.

Station 36: Red-brown leachate staining, light and very small in area (few square centimetres) is scattered along the landfill toe; occasional seep still active.

Station 37: Leachate seep occurring on south side of pump house compound.

Station 41: Spring observed in May is not visible at this time, if flow is reduced it may be obscured by vegetation; stream is at low flow conditions; a deep trench has been dug into the landfill at this location to investigate the toe drain.

Station 43: Thin "stream" of leachate about 5 to 8 cm wide seeping towards ditch.

Station 45: Leachate springs are occurring at toe of slope of landfill.

Station 48: Several small active leachate seeps and stained soil areas (dry seeps) occur along base of landfill; vigorous vegetation grows along ditch, all seepage staining is faint reddish-brown and small in area.

Station 49: Small active and inactive leachate seeps, with reddish-brown staining on soil.

Station 50: Active leachate seep, about 30 cm wide is located about 2 m above toe of slope; the vegetation in the ditch is locally stressed (2-3 $m^2$) where leachate enters it. Along the base of landfill from Stations 33 to 50, there is evidence of previous small leachate seeps; the ditch water is scummy, with faint leachate odor in some locations; Cattail growth appears vigorous.

## 4.5 Autumn Data 1980

### 4.5.1 Sensing Conditions

The November 1980 imagery was obtained under late autumn conditions. Deciduous trees were leaf-free, and temperatures were around freezing (0°C). An earlier snowfall which covered the site during the 18 November field visit, had melted. Weather conditions prior to 26 November are listed in Figure C.6.

Autumn is one of the more effective data acquisition periods for thermography. Cold nighttime temperatures provide a thermally flat background for easier detection of leachate outbreaks. Relatively dry soil moisture conditions do not

Figure C.10 Leachate seepage on Oakville Landfill; Note colour of leachate and surrounding "halo" of dead grass. Cattails in ditch have been killed by seepage.

complicate the thermal pattern with mottling. Despite these favourable aspects, the imagery was level-sliced (Volume 1) in order to enhance thermal anomalies.

The imagery is, in places, "noisy", due to a mechanical problem in taping of the data during acquisition. The problem is impossible to rectify on this particular imagery.

The expansion area is now being landfilled, and the main site is closed. Construction of a service access road and deepening of ditches has obscured leachate seepage along the northwest and southwest toes of the closed site.

### 4.5.2 Diagnostic Features

Observations are Located on Figure C.11.

a) Colour

Reddish-brown staining and dark soil tones identify leachate seepage. All observations correlate to previous locations (compare station locations on Figures C.7, 8 and 9).

Station 55: Darker zone of possible seepage visible in grass cover.

Station 54: Red-brown stain visible at leachate seep and spring at the north end of toe drain, partly obscured by road.

Station 56: Large leachate seep is visible as clear red--brown stain; the slope has been recontoured where the seep entered the perimeter ditch.

Station 57: Dark tone on final cover may be zone of seepage.

Station 62: Very faint reddish-brown staining is visible at toe of landfill; however, this may be a final cover soil colour.

b) Colour Infrared

Staining indicators are less distinct on the colour infrared than on the colour photography. Scattered dark soil tones (blue green tone) indicate high moisture content areas in the soil; most of these are not leachate features.

Observations located on Figure C.11 are as follows:

Station 54: Leachate seep is visible as gully in shadow.

Station 56: Leachate seep is clearly visible as black tone; a sparse zone of healthy vegetation (red tone) is detected around the stain, and a small distance from the stain.

Station 57: The possible seepage area visible on colour is seen as dark, green black tone.

Station 58: The dark blue-green tone observed around the pump house compound, where leachate seep was observed in field, occurs wherever the final cover has a higher moisture content.

Ministry of the Environment
Ontario

# C·11 Autumn data
## ( Nov. 1980 )

●65 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS
COLOUR PRINT
– GR58C164-18
COLOUR INFRARED PRINT
– GR58C163-26,31

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

c) Thermography

The November thermography for the Oakville landfill was taken under ideal conditions, resulting in clear thermal anomalies on the analog imagery. These anomalies are described as follows and the stations are located on Figure C.11.

Stations 51, 59, 60: Leachate seepage appears on the thermography as a very bright, intense thermal anomaly. This characteristic appears to hold true, even using analog imagery. All of these sources have been previously identified on the photography.

Station 58: This corresponds to the pump house location and there is an obscure leachate seep here. The anomaly is thermally warm and the signature appears cooler than the more vigorous seeps.

Station 63: Warm anomalies identify seepage along stream bank; note Station 68, Field Observations - measurements on seep from north bank.

Station 69: A somewhat cooler (darker) area than at Station 58 is identified, this may correspond to surface water ponds.

Stations 71, 70: Ponding appears as a warm thermal anomaly on the thermography.

Station 72: Leachate recharge well produces bright thermal anomaly.

d) Field Observations

Most leachate seepage observed in November had been previously mapped. Road construction obscured many seeps along the landfill toe, and a light snow cover at the time of the field visit may have obscured other features.

Detailed observations:

Station 52: North slope recontoured with new fill, and ditch re-excavated.

Station 53: Leachate seep into ditch; faint reddish-brown discolouration on snow in ditch; conductivity 5,000 us.

Station 54: Leachate seep, previously described.

Station 56: Leachate seep, previously described.

Station 58: Leachate seep in northeast corner of pump house compound; partly obscured by grasses.

Station 60: Leachate spring at toe of slope has changed from May observation; leachate is clear, lower flow; temperature 8.5°C; strong odor no vegetation kill; cattails adjacent to spring; stream, just below spring; - 1.1°C temperature; 2,500 us conductivity.

Station 61: Leachate seep, with melted snow and discoloured snow; temperature 2°C; no conductivity.

Station 64: Small leachate seeps.

Station 65: Snow covered pool of leachate mixed with surface runoff adjacent to base of landfill; snow is discoloured on pool; conductivity of 'pond' 4,000 us.

Station 66: Leachate seep.

Station 67: Leachate spring is flowing into new refuse excavation where excavation cut into old garbage.

Station 68: Spring in stream bank 5.50°C temperature; 2,000 us conductivity.

# 5. ANALYSIS

## 5.1 Archival Photography

Archival photography at Oakville defines the existence and extent of the landfill activity. In comparing the pre-landfill photography (1954) and the most recent photography (1978), three features identify the landfill:

i) diversion of original drainage;

ii) development of obviously man made rectangular mound at the main site;

iii) disturbed lands south of the main site.

The interim photography defines the stages of development and gives a time period for operation of the closed section south of the site (1972 to 1978). Landfilling is known to have occurred in this southern area. However, if landfilling activity were only suspected, the archival photography would give investigators a definite time period to target when researching records or the public's memory.

The archival photography has allowed the landfill designers to predict the possible route of leachate migration through and away from the site. This route coincides with the original drainage path that was buried by the landfill (B, Figure C.5). This discharge area has been controlled. A current leachate spring coincides with the location of a working trench (1965, A, Figure C.5).

## 5.2 Photographic Indicators

Colour and colour infrared photography identifies leachate seepage at Oakville by direct detection and by the use of inductive interpretation. The indicators interpreted on the photographs are staining, seepage, gullies and vegetation.

a) Staining

Surface staining is the main indicator interpreted on the colour and colour-infrared photographs at Oakville. It varies from very dark to faint red-brown tones on the grass and soil cover, and is observed on-site, around the landfill perimeter.

Dark, almost black leachate staining is observed on the grassed landfill face in a corner of the site. One very distinct seep (about 2 m wide) is clearly visible on colour and colour-infrared imagery.

However, most seepage is indicated by very faint red-brown staining of soil or snow. Some leachate staining is more distinct in summer - contrasting more clearly with the soil - but this applies to only a few seeps. Generally, staining is small and it contrasts poorly with the soil cover. Just barely detectable on colour photography, most of this staining is not visible on colour infrared photography.

Red-brown coloured runoff pools also mask leachate seepage staining on the photography. The red-brown tone is derived from the final soil cover. On the photography, it is not possible to distinguish between simple

runoff ponding and ponding where direct leachate seepage may be occurring.

Site closing activity (road construction, soil cover application, expansion excavation) covered seepage staining in the November imagery. Changing surface conditions on the site also inhibit chance for staining to develop to a stage where it is detectable.

b) Seeps

Dark soil tones in late winter, spring and autumn photography identified a line of "incipient" seepage on the grassed portion of the landfill. Active seepage along this line (about 40 m long) was restricted to two individual outbreaks (about 2 m wide) - both identified by dark surface staining and vegetation kills.

No other clear seepage zones were identified. Final soil cover application and grading over the remainder of the site prevented visual development of seepage lines.

c) Gullies

Two snow-filled gullies beginning mid-slope on the landfill face identify leachate springs on the March photography. The springs were either inactive or flow was too low to melt the snow.

The discontinuous snow cover enhanced the detection of these indicators; continuous snow cover would have obscured them.

d) Vegetation

Two vegetation indicators are identified:

i) vegetation kills related to leachate seeps in the grassed area of the landfill. The grass is killed in the area of seepage, with cattails dying where a new active seep entered the drainage ditch. Only a few square metres are affected, and dead vegetation rapidly grades into healthy vegetation away from the seepage; and

ii) positive vegetation stress related to greater moisture of leachate. Only a few plants are affected in two isolated locations.

Other vegetation stress around the site is inconclusive. Vegetation gaps are mainly natural, where vegetation cover occurs on-site. No relationship is apparent between stress in vegetation off of the site and on the landfill.

## 5.3 Thermography

Analysis of thermography at Oakville concentrated on thermal anomalies close to the existing site. Generally, only these anomalies are listed in the study results. Anomalies of similar intensity and shape, but apparently not related to the site (by geology setting or prior identification), have not been located.

The anomalies at Oakville can be roughly grouped by the intensity of their thermal signature:

a) Seepage

Thermally detected seepage discharge generally appears as distinct points, much warmer (brighter) than the background. The contrast between the anomaly and background is lower in April, due to season changes. There is no distinction between natural ground water seepage and leachate seepage.

However, the most vigorous leachate spring at Oakville appears as only a "warm", poorly defined anomaly in March. This may be due to interference from snow or vegetation cover, since it is detected on the April and November imagery.

The same bright distinct signature occurred at the leachate recharge well.

b) Ponding

Numerous warm irregular anomalies were identified on the thermography. These are less intense than seepage anomalies.

Generally, these anomalies related to surface ponding. However, there was no means to distinguish between leachate contaminated and simple runoff ponding.

## 5.4 Sensor Evaluation

Archival photography was useful in defining the landfill boundaries. Also, by defining the existence of natural drainage courses through the filled areas, it was possible to predict the location of future leachate paths. In the case of this site, the interpretation of sequential, archival photography was one of the most useful applications of remote sensing.

Of the 1980 photography, spring and summer colour imagery is most successful in identifying leachate seepage. (Figure C.12.)
Red-brown staining - the main indicator at this site - is more completely detected on the colour than the colour infra-red photography. Lack of vegetation on-site, and the lack of detectable impact on vegetation surrounding the landfill, minimized the use of colour infrared film for identifying vegetation stress.

Many leachate seeps and springs are not detected by the photography (see Figure C.12). The detection of small seeps (<.3 m width) at the toe of the landfill and springs and seeps along the perimeter ditch is poor. A vigorous spring, (Station 60, Figure C.11) flowing into the easterly tributary, and associated pollution is not picked up by any photography. The small size of springs and often vigorous vegetation cover prevents their resolution on the photography.

FIGURE C.12

1980 SENSOR EVALUATION

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Late Winter | | | | |
| 1 | Leachate spring | N | N | I |
| 2 | Leachate seep | Y | N | Y |
| 3 | Grass cover | Seep line | Seep line | N |
| 4 | Leachate spring | Y | Y | Y |
| 5 | Leachate seep | Y | N | Y |
| 6 | Leachate seep | Y | N | Y |
| 7 | Pond | Y | Y | Y |
| 8 | Stream | Y | Y | Seeps |
| 9 | Recharge well | Y | Y | Y |
| Spring | | | | |
| 10 | Leachate seeps | Y | I | Y |
| 11 | Leachate seeps | Y | N | N |
| 12 | Leachate springs | Y | N | N |
| 13 | Leachate springs | Y | Y | N |
| 14 | Grass cover | Seep | Seep | N |
| 15 | Leachate seeps | Y | N | N |
| 16 | Leachate seeps | Y | N | N |
| 17 | Leachate seeps | Y | N | N |
| 18 | Leachate seeps | Y | N | N |
| 19 | Leachate seeps | N | N | N |
| 20 | Ground water seep | N | N | N |
| 21 | Leachate seep | N | N | N |
| 22 | Leachate spring | N | N | Y |
| 23 | Leachate seep | N | N | N |
| 24 | Leachate seep | N | N | N |
| 25 | Pond | N | N | N |
| 26 | Stream seep | N | N | Y |
| 27 | Pond | I | I | N |
| 28 | Pond | I | I | N |
| 29 | Pond | I | Y | Y |
| 30 | Pond | I | I | Y |
| 31 | Pond | I | I | Y |
| 32 | Recharge well | Y | Y | Y |
| Summer | | | | |
| 33 | Natural gap | Y | Y | |
| 34 | Leachate spring | Y | Y | |
| 35 | Leachate spring | Y | Y | |
| 36 | Leachate seep | I | N | |

FIGURE C.12
1980 SENSOR EVALUATION
(continued)

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Summer - (cont'd) | | | | |
| 37 | Leachate seep | I | N | |
| 38 | Vegetation | I | I | |
| 39 | Vegetation | N | I | |
| 40 | Vegetation | N | I | |
| 42 | Vegetation | N | I | |
| 43 | Leachate seep | Y | I | |
| 44 | Leachate seep | N | N | |
| 45 | Leachate seep | Y | I | |
| 46 | Leachate seep | Y | I | |
| 47 | Leachate seep | N | N | |
| 48 | Leachate seep | N | N | |
| 49 | Leachate seep | N | N | |
| 50 | Leachate seep | Y | N | |
| Autumn | | | | |
| 51 | Snow filled ditch | N | N | Seep (I) |
| 52 | Snow filled ditch | N | N | N |
| 53 | Leachate seep | N | N | N |
| 54 | Leachate seep | Y | Y | N |
| 55 | Snow covered grass | Seep | N | N |
| 56 | Leachate seep | Y | Y | N |
| 57 | Snow covered soil | I | I | N |
| 58 | Leachate seep | N | I | I |
| 59 | Snow covered soil | N | N | Seep |
| 60 | Leachate spring | N | N | Y |
| 61 | Leachate seep | N | N | N |
| 62 | Snow covered soil | I | N | N |
| 63 | Stream seepage | N | N | Y |
| 64 | Leachate seep | N | N | N |
| 65 | Leachate pond | N | N | N |
| 66 | Leachate seep | N | N | N |
| 67 | Leachate spring | N | N | N |
| 68 | Stream bank spring | N | N | Y |
| 69 | Snow covered soil | N | N | Pond |
| 70 | Snow covered soil | N | N | Pond |
| 71 | Snow covered soil | N | N | Pond |
| 72 | Recharge well | Y | Y | Y |

Y - feature identified
N - not identified
I - inconclusive or indistinct

Except for two large seeps - associated with a mid-slope gully, vegetation kill and staining - identification of seepage is often inconclusive. Most sites, identified on the photography and on the thermography, require field confirmation.

The thermography identified some seepage points not visible on the photography. However, despite data manipulation using level slicing techniques, many seepage areas were not detected. Most noticeable are the seeps, small and large, along the west side of the landfill.

In addition, all anomalies had to be field checked, since it was not possible to distinguish landfill related from natural seepage and ponding on the imagery.

No individual sensor detects all leachate seepage. Thermography - after considerable data processing to distinguish very fine temperature differences - identified some large seeps but still missed many small seeps along the west side of the site. In addition, it does not distinguish natural ground water seepage from leachate contaminated seepage, and all features must be field checked. Colour photography is more successful than colour infrared in distinguishing subtle tonal changes that identify most of the leachate staining at Oakville.

## 6. CONCLUSIONS

Archival photography - combined with an interpretation of the hydrogeologic environment of the site is the most cost effective method of determining leachate migrations at the Oakville site.

The archival photography can be interpreted by a qualified hydrogeologist to determine the probable hydrogeological environment at the site. In addition, this photography will show the old drainage paths that originally existed under the site. These will be likely paths along which leachate will travel.

The colour photography was useful in determining areas of staining which were the result of outbreaks of leachate along the toe of the landfill. However, scrub vegetation along the toe obscured some staining. Contrast of the reddish stains with the red soils derived from the Queenston Shale was poor and detracted from the positive attributes of the colour photography.

The colour infrared - valuable for its vegetation stress characteristics - was less suitable since there was a general lack of vegetation around the site and the landfill had very little impact on this vegetation.

Thermography was successful in locating areas of thermal contrasts - springs of warm seepage from areas of cold background. The causes of these anomalies had to be verified by field mapping techniques. During field mapping, however, it was discovered that several seepage areas were not detected on the thermography.

## 7. IMAGERY USED AT THE OAKVILLE SITE

### 7.1 Archival

Archival photographs used at this site are:

| Year | Scale | Photo Number | Source |
|---|---|---|---|
| 1954 | 1:15840 | 4321-25 #245-247 | M.N.R. |
| 1959 | 1:30000 | A17176 #68-70 | N.A.P.L. |
| 1965 | 1:16000 | A18950 #13-15 | N.A.P.L. |
| 1972 | 1:15840 | 4320-4 #221-222 | M.N.R. |
| 1978 | 1:10000 | 433-57 #116-227 | M.N.R. |

### 7.2 1980 Imagery

Figure C.4 shows the area covered by the 1980 imagery. Scales, date, and target photographs are given for each imagery set.

### 7.3 Sources

A complete set of imagery is available for viewing at the following offices of the:

Ontario Ministry of the Environment:
Solid Waste Unit
Waste Management Branch
Ontario Ministry of the Environment
4375 Chesswood Drive
Downsview, Ontario
M3J 2C2

Central Region
Ontario Ministry of the Environment
Suite 700, 150 Ferrand Drive
Don Mills, Ontario
M3C 3C3

Copies of imagery may be obtained from:

Archival:

N.A.P.L.: National Air Photo Library
Energy Mines and Resources
615 Booth Street
Ottawa, Ontario
K1A 0E9
Telephone: (613) 995-4560

M.N.R. Public Service Centre
Ontario Ministry of Natural Resources
Whitney Block
Queen's Park
Toronto, Ontario
M7A 1W3
Telephone: (416) 965-1123

1980 Imagery:

Contact: Ontario Ministry of the Environment
Solid Waste Unit

# Appendix D
# Bayview Park site

## Remote Sensing Techniques & Waste Management Assessments

# 1. INTRODUCTION

The Bayview Park landfill site is located north of Burlington on the King Road (Figure D.1). It is one of six southern Ontario landfills used in the study "Remote Sensing Techniques and Waste Management Assessment", prepared for the Ontario Ministry of the Environment. The purpose of the study is to evaluate specific remote sensing techniques for application to landfill monitoring and identification.

Colour and colour infrared aerial photograpy, and thermo graphy was acquired during 1980. This imagery, along with archival photography was interpreted for application in monitoring and identifying existing landfill sites. A summary of the results, comparative evaluation of techniques and final study conclusions are presented in Volume 1 of this report.

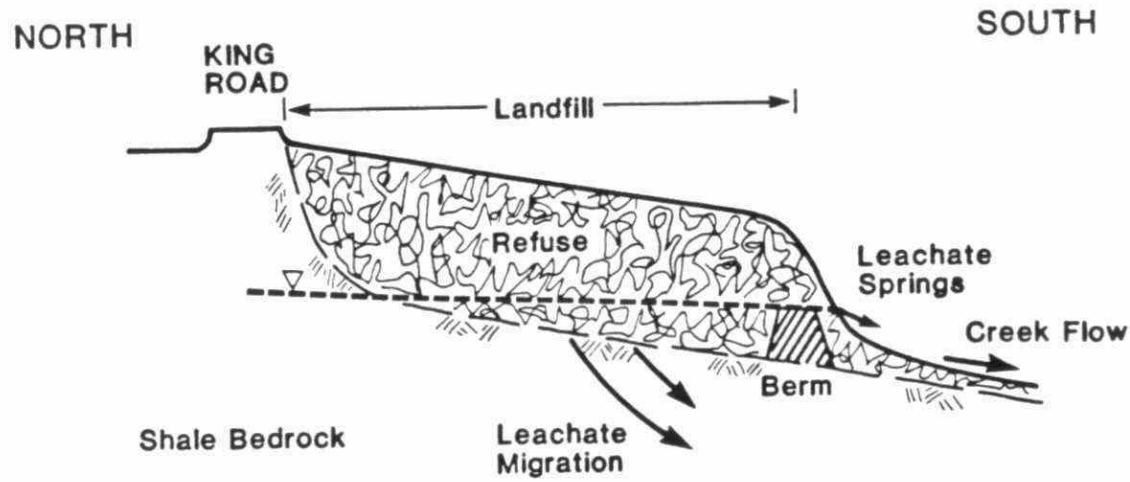
This appendix contains the detailed results for the Bayview Park site only. The appendix is one of six similar appendices comprising Volume 2. Together they provide all the detailed observations and data accumulated during this study. Each appendix is designed to be used separately with Volume 1, (the general text) if desired.

## 2. BACKGROUND

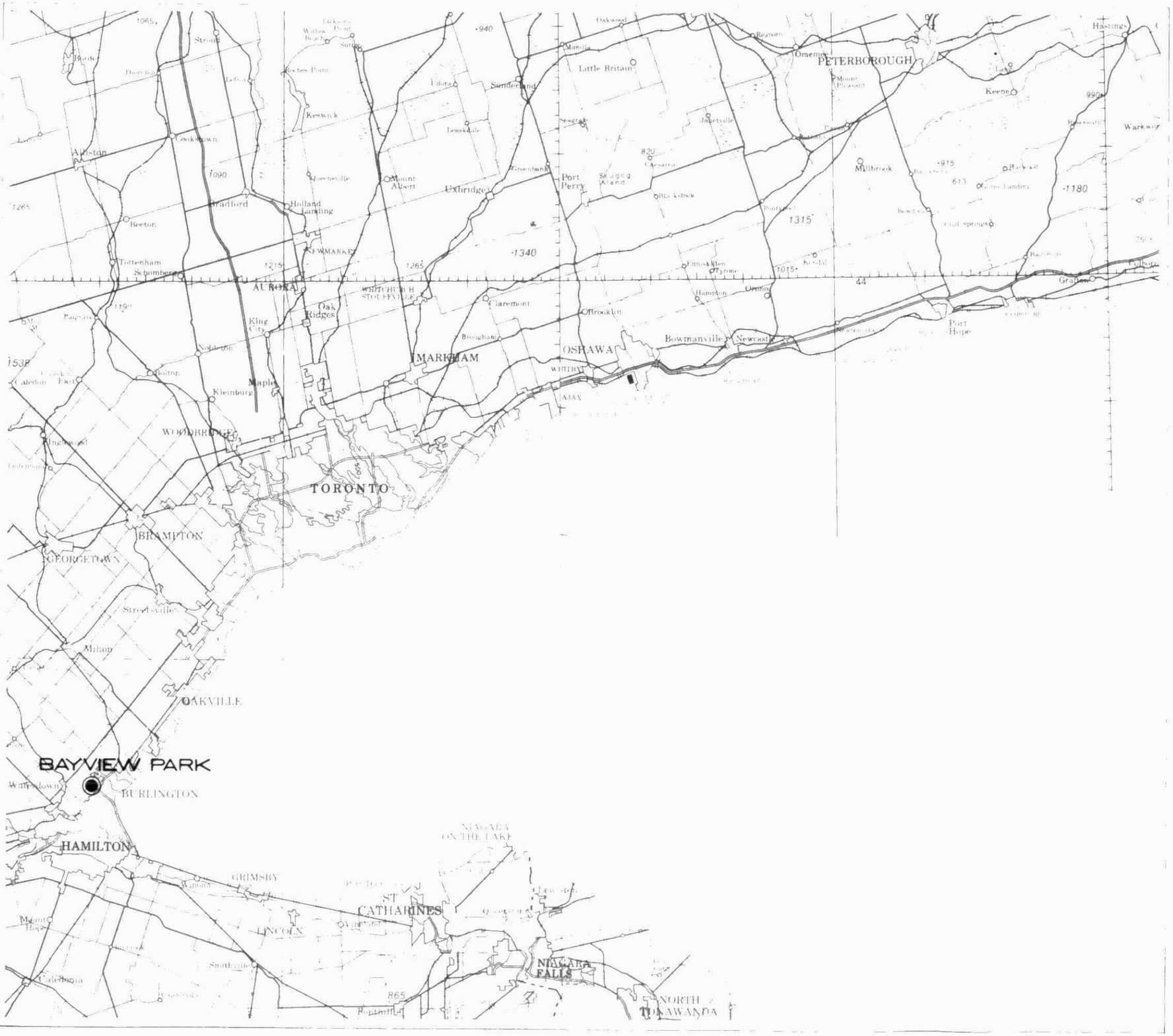
### 2.1 Physical Setting

Bayview Park landfill is located in the same rugged bedrock terrain as the nearby Burlington landfill (Figures D.2, D.3). The surrounding lands are deeply dissected by gullies and shale pit workings. Overburden is very shallow, and the red-brown Queenston shale outcrops frequently. The landfill forms a gently sloping mound within this environment. (See drawing).

Schematic Cross Section of Bayview Park Landfill




Leachate discharges along the southern edge of the closed site. The location of several vigorous springs coincides with former north-south gullies, now filled with refuse. The springs indicate that leachate mounds within the landfill and flows towards the south end of the site. This agrees with the direction of original surface water flow and with




Ministry of the Environment

Ontario

# D·1 Location map

● SITE LOCATION (CLOSED)

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED

GARTNER LEE & ASSOCIATES LIMITED

ONTARIO CENTRE FOR REMOTE SENSING

MINISTRY OF NATURAL RESOURCES

Ministry of the Environment
Ontario

# D·2 Physical setting

LANDFILL SITE

SHALE & TILL BEDROCK COMPLEX

ERODED BEDROCK SLOPES

WATER COURSES

WETLANDS

ACTIVE SHALE PIT

BASED ON 1980 PHOTOGRAPHY

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED

AND
GARTNER LEE ASSOCIATES LIMITED
AND
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Ministry of the Environment
Ontario

# D·3 Site plan

PROPERTY BOUNDARY

LANDFILL LANDFORM SIDE SLOPES

NO LEACHATE COLLECTION SYSTEM

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED

[illegible]
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

the general direction of ground water flow, observed at the adjacent Burlington site. Leachate also enters the bedrock beneath the site and migrates in a southerly direction through the shale.

Surface runoff and leachate discharges into several unnamed tributaries of Indian Creek. Most of these southward draining gullies have only intermittent flow. However, constant seepage of leachate has encouraged cattail growth and wetland conditions along drainage courses immediately south of the site (Figure C.2).

## 2.2 Site History

It is estimated based on available information that landfilling at the Bayview site began in 1952 and continued until 1972. Situated on a former shale extraction area, virtually all of the 18 hectare site property was used for landfilling. A concrete tunnel for a mine railway between the site and extraction operations to the east of King road has been filled and is the only visible sign of former operations. The completed site is being used by the City's Parks and Recreation Department primarily for equestrian activities and for future passive uses.

Wastes landfilled during the site's operating life were residential, commercial and industrial in nature generated from City of Burlington and its surrounding area. Landfilling was carried out to an average depth of 10-15 m. As the site is incised by a number of deep gullies, shale berms were constructed across these gullies at the northern limit of landfilling to impound leachate flow at the base of the site and thus prevent its breakout.

In 1975 investigations were carried out to monitor the presence of methane gas. Although detected within the site area, methane was not found beyond site boundaries.

In 1978 leachate was noted discharging from the south end of the site into marshy areas at the base of the ravines. It has been assumed that impounded leachate is overflowing the control dykes constructed earlier.

In 1978 surface drainage over the site's south slopes has eroded the site final cover and exposed refuse. On-going maintenance is being carried out by the City to restore eroded areas.

## 3.0 METHODOLOGY

The prime objective of the study was to evaluate remote sensing techniques for thier applicability to waste management programs. Six sites were selected for the study and a program for acquisition of remote sensing data for the sites was developed.

Four remote sensors were selected for the study:

i) colour aerial photography
ii) colour infrared aerial photography
iii) aerial thermography
iv) archival photography

Each sensor was expected to be capable of providing specific data on the condition of each site - in particular the discharge of leachate (colour aerial photography and aerial thermography). The sites selected represented a range of differing hydrogeological conditions, with a known history of surface discharge of leachate, and with various stages of site operation and site rehabilitation.

The selected sites were:

Cobourg Landfill Site
Whitby Landfill Site
Oakville Landfill Site
Bayview Park Landfill Site (in Burlington)
Burlington Landfill Site
Upper Ottawa Street Landfill Site -
(in Hamilton)

The program for evaluation of sensors comprised initially the acquisition and revew of hydrogeological assessments made for

the site through previous studies. In addition, to assist in providing an understanding of site history and past operations, archival photography was obtained dating back to the pre-landfill period and taken at intervals ranging from 5 to 7 years to the present. To further assist in constructing a site development history, a review of Ministry files for the site was made. Observations of site operations and leachate discharge were reported and give insight on the development of leachate mounding and on operational procedures which have conributed to present site conditions.

The schedule for remote sensing data acquisition was:

| Sensor | Flight Date | Field Reconnaissance |
|---|---|---|
| colour photography | 12 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 17 June 1980<br>6 August 1980<br>18 November 1980 |
| colour infrared photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 17 June 1980<br>6 August 1980<br>18 November 1980 |
| thermography | 4 March 1980<br>17 April 1980<br>26 November 1980 | 17 June 1980<br>6 August 1980<br>18 November 1980 |

Photography scale was changed from 1:8000 for March and April flights to 1:6000 for July and November flights. Average flying altitude for thermography was 1050 m, giving an approximate scale of 1:14000. Data acquisition details are given on Figure D.4.

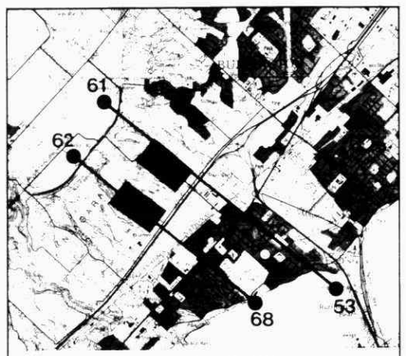
After each flight, photography and imagery were examined and preliminary interpretations made. Detailed field reconnaissance was made to confirm interpretations and to identify features undetected on the sensor data. Photography

and imagery for each flight were annotated and annotations for subsequent flights compared so that assessment of the relative effectiveness of sensors under varying seasonal conditions would be made.

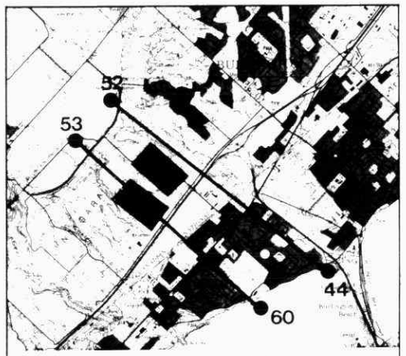
Following completion of all data acquisition, interpretations and field work, comparative assessments of data with respect to season, sensor type, and type and extent of features sensed were made. Site features detectable in the field were noted and compared to those interpreted from photography and imagery. These records and interpretations were used as a basis for determining the effectiveness of each technique.

The relative merits of the various sensors in satisfying the study objective and taking into account relative costs of data acquisition were then assessed.

TRUE COLOUR




DATE: MARCH 12, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80004
TARGET EXPOSURES: (BAYVIEW PARK: 58, 59, 63, 64, 65)
(BURLINGTON: 63, 64, 65)

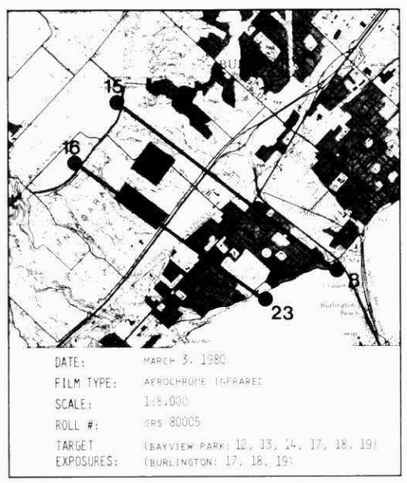



DATE: APRIL 17, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80027
TARGET EXPOSURES: (BAYVIEW PARK: 49, 50, 51)
(BURLINGTON: 54, 55, 56)

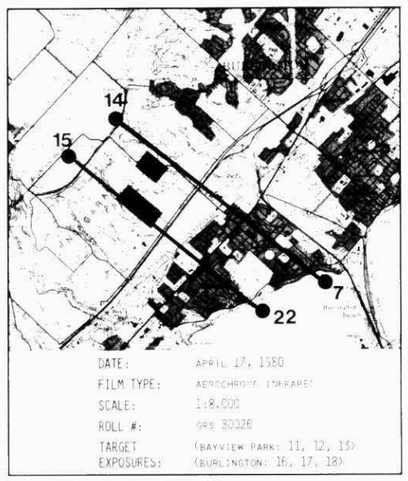
DATE: JULY 25, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80110
TARGET EXPOSURES: (BAYVIEW PARK: 12, 13, 14, 17, 18, 19)
(BURLINGTON: 17, 18, 19, 23, 24, 25)

DATE: NOVEMBER 22, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: GRS 80144
TARGET EXPOSURES: (BAYVIEW PARK: 23, 24, 25, 28, 29, 30)
(BURLINGTON: 28, 29, 30, 34, 35, 36)

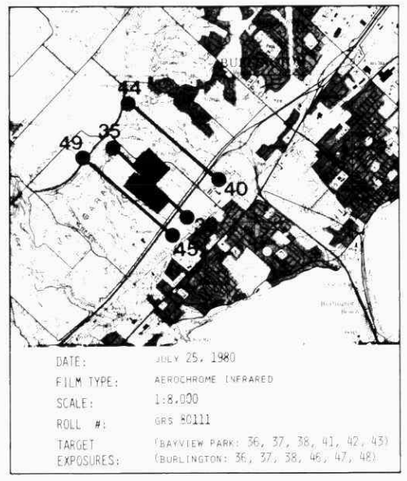
COLOUR INFRARED



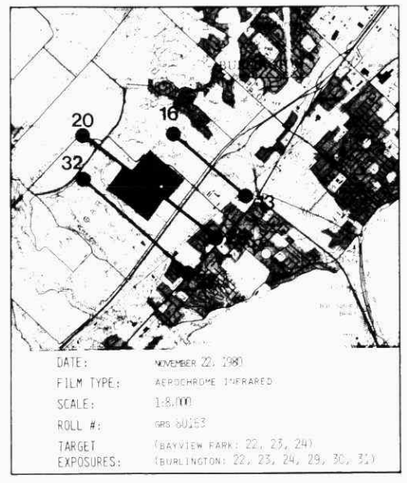

DATE: MARCH 3, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80005
TARGET EXPOSURES: (BAYVIEW PARK: 12, 13, 14, 17, 18, 19)
(BURLINGTON: 17, 18, 19)




DATE: APRIL 17, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80026
TARGET EXPOSURES: (BAYVIEW PARK: 11, 12, 13)
(BURLINGTON: 16, 17, 18)




DATE: JULY 25, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80111
TARGET EXPOSURES: (BAYVIEW PARK: 36, 37, 38, 41, 42, 43)
(BURLINGTON: 36, 37, 38, 46, 47, 48)




DATE: NOVEMBER 22, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: GRS 80163
TARGET EXPOSURES: (BAYVIEW PARK: 22, 23, 24)
(BURLINGTON: 22, 23, 24, 29, 30, 31)

THERMOGRAPHY

DATE: MARCH 4, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN

DATE: APRIL 17, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN

DATE: NOVEMBER 22, 1980
SENSOR: THERMOGRAPHY
CONDITIONS: PRE-DAWN

LATE WINTER | SPRING | SUMMER | AUTUMN

Ministry of the Environment
Ontario

# Bayview Park site

# D·4 Data Acquisition (1980)

0 2 kilometres

## Remote Sensing Techniques & Waste Management Assessment


M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

# 4. STUDY RESULTS

## 4.1 Archival Photography

The archival photography traces the development of the Bayview Park site from shale extraction in 1942 to closure and redevelopment by 1978. The sequence of landfilling and drainage diversion is plotted on Figure D.5. Significant features observed on the photographs are outlined below.

Before landfilling (1942, 1954), the site is identical to surrounding lands - rugged topography with extensive bedrock exposures along gullies. Surface runoff drains along well developed north-south channels. Shale extraction had ceased by 1954.

In 1965, landfilling is already occurring over the southern two-thirds of the site. The gullies are filled with refuse and drainage coming from the north (upslope) is being diverted to the gully west of the site. Apparently some landfilling has occurred in the shale pit east of King Road (Area B, Figure D.5); however, there is no means to determine if this area is clean fill or refuse and clean fill.

By 1972, the site has expanded to its present limits, and forms a uniform mound in the gullied terrain. Final soil cover is being applied to most of the site. Surface runoff is diverted completely around the site. By 1978, the site is being used for riding school.

The landfill mound (1972, 1978) is a very distinct topographic feature on the photography. It clearly defines the western and southern extent of the refuse. However, it is not clear from the 1972 photography whether landfilling

extends northward right up to King Road, or whether a small area is still natural soil (Area A, Figure D.5).

## 4.2 Late Winter Data 1980

### 4.2.1 Sensing Conditions

The late winter imagery was flown during the first week of March. Unfortunately, snowfall was low during this 1979/1980 season, and in early March, snow accumulations were confined to protected areas. A continuous white background may have improved detection of leachate discharge on the photography; it may also have obscured seepage. The lack of snow cover did not seriously affect the thermography. Although the desired flat or thermally uniform background was not obtained, the frozen soil and water surfaces still provided good thermal contrasts. Weather conditions preceding 4 March 1980 are listed in Figure D.6.

### 4.2.2 Diagnostic Features

a) Colour

Despite the lack of general snow cover, snow gaps are noted at two possible leachate springs at the south end of the landfill. A stream-like gap extending from the landfill face is a fairly strong indicator of leachate seepage. Discoloured snow and surface gullies on the site may be natural features.

Ministry of the Environment
Ontario

# D·5 Archival photography

LANDFILL BOUNDARIES

EXTENT OF LANDFILL 1965

EXTENT OF LANDFILL 1972, 1978

A TEXT REFERENCE

SURFACE DRAINAGE CHANGES (1965)

SURFACE DRAINAGE CHANGES (1972, 1978)

NOTE: BASED ON 1942, 1954, 1965, 1972 AND 1978 AIR PHOTOGRAPHS

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED

in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

FIGURE D.6

WEATHER DATA[1]: BAYVIEW PARK LANDFILL

| DATE | TEMPERATURE (°C) | | | |
|---|---|---|---|---|
| | Maximum | Minimum | Mean | Precipitation[2] |
| Late Winter | | | | |
| February 27 | - 1.0 | - 8.0 | - 4.5 | Tr (S) |
| 28 | - 6.0 | -14.0 | - 1.0 | |
| 29 | -12.0 | -21.0 | -17.5 | |
| March 1 | -12.0 | -19.0 | -15.5 | |
| 2 | - 5.0 | -17.0 | -11.0 | |
| 3 | 6.0 | -16.0 | - 8.0 | |
| 4 | 5.0 | - 5.0 | 0.0 | 5 (R) |
| Spring | | | | |
| April 12 | 12.0 | 4.0 | 7.0 | 2.8 (R) |
| 13 | 9.0 | 1.0 | 5.0 | 1.0 (R) |
| 14 | 7.0 | 1.0 | 4.0 | 7.6 (R) |
| 15 | 4.5 | 3.0 | 4.0 | 8.0 (R) |
| 16 | 4.5 | - 4.0 | 0.0 | |
| 17 | 4.5 | - 5.0 | 2.0 | |
| Summer | | | | |
| July 20 | 29.9 | 23.0 | 26.0 | 1.0 (R) |
| 21 | 32.5 | 21.0 | 27.0 | 3.0 (R) |
| 22 | 33.0 | 20.0 | 26.5 | 7.1 (R) |
| 23 | 28.0 | 16.5 | 23.0 | |
| 24 | 29.0 | 14.5 | 21.5 | |
| 25 | 30.0 | 18.5 | 24.5 | |
| 26 | 25.0 | 19.0 | 22.0 | |
| Autumn | | | | |
| November 17 | 3.0 | - 4.0 | - .5 | .7 (S) |
| 18 | 5.0 | - 2.5 | .5 | |
| 19 | 4.0 | - 5.0 | - .5 | |
| 20 | 8.5 | - 2.0 | 3.0 | |
| 21 | 7.0 | 1.0 | 4.0 | |
| 22 | 9.0 | - 1.0 | 4.0 | |
| 23 | 8.0 | .5 | 4.0 | |
| 24 | 7.0 | 6.0 | 6.5 | 3.8 (R) |
| 25 | 2.5 | 0.0 | 2.0 | |
| 26 | 5.0 | - 4.5 | 0.0 | |
| 27 | 3.0 | - 8.5 | - 2.0 | Tr (R) 3.3 (S) |

1. Source: Burlington weather station
2. (R) rain in mm
   (S) snow in cm
   (Tr) trace of precipitation

The following detailed observations are located on Figure D.7, by station number.

Station 1: Possible leachate spring on landfill slope appears to have melted snow along valley for approximately 30 m; ("stream like" gap in snow cover).

Station 2: Small snow gap at the landfill toe may locate active leachate discharge; gully adjacent to spring may be caused by surface runoff or leachate seepage flow from higher in the landfill.

Station 5: Gully caused by surface runoff erosion (see drainage pattern Figure D.2).

Station 6: Pond along stream with discoloured snow surface appears to be created by runoff from horse barn.

b) Colour Infrared

Snow gaps and other dark tone indicators of leachate seepage are less clear on the colour infrared than on the colour film. Contrast is poor between the dark seepage tones and the dark blue false colour soil tones.

The following detailed observations are located on Figure D.7, by station number.

Station 1, 2, 9A: Dark areas suggest seepage from landfill slope; less distinct than on colour because of lower contrast.

Station 5: Gully.

Station 7: Apparent seepage towards stream; poorly defined.

Ministry of the Environment
Ontario

# D·7 Late winter data (March 1980)

● 8 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT – GRS80004-59
COLOUR INFRARED PRINT – GRS80005-13

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

c) Thermography

Thermal anomalies are located on Figure D.7 and described briefly below.

Stations 1, 2, 3, 9 and 9A: Bright (hot) anomalies around the landfill perimeter indicate possible leachate contaminated springs; discrete points on thermography.

Station 4: Bright (hot) anomaly surrounded by warm (light) area, on landfill slope; possible leachate discharge.

Station 7: Warm anomaly on landfill may indicate leachate seepage.

Station 8: Cold (dark) anomaly on road; corresponds to tunnel under King Road; tunnel now mainly filled, and a culvert carries surface runoff beneath road.

## 4.3 Spring Data 1980

### 4.3.1 Sensing Conditions

The spring data was obtained on 17 April 1980 under good conditions - leaf-free deciduous trees, high water table and high runoff conditions. While these conditions are excellent for photography, the high soil moisture increased background noise on the thermography. As a result, the thermal data had to be level-sliced to enhance anomalies. Weather data prior to 17 April 1980 are listed in Figure D.6.

4.3.2 Diagnostic Features

a) Colour

Seepage on the spring colour photography is indicated by dark soil tones. Red-brown staining on the site may be due to runoff from the red-brown soils.

The following detailed observations are located on Figure D.8.

Station 12: Leachate seepage (dark tone) at toe of landfill (Station 2).

Station 13: Two leachate seeps (dark tone) on grassed landfill slope, just above road; see evidence of flow across road.

Station 14: Manure and leaf piles, with dark seepage occurring from base of pile.

Station 15: Dark rectangular feature - pool of water.

Section 18: Brown surface staining may be due to runoff from horse ring.

Station 19: Dark tone on grass possible seepage area; no runoff source adjacent.

Station 22: Runoff gully or leachate seepage/runoff gully?

Ministry of the Environment
Ontario

# D·8 Spring Data
(April 1980)

●17 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80027-50
COLOUR INFRARED PRINT
– GRS80026-12

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
[illegible]
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

b) Colour Infrared

Seepage is generally less distinct on the colour infrared than on the colour photography. At several locations, shadows obscure seepage points. However, early vegetation growth (red tone) associated with one seepage area provides additional indications that leachate (warm, moist) is discharging at that location.

Observations are located on Figure C.8, and described below.

Station 12: Very indistinct with site largely in shadow.

Station 13: Dark (greenish) tone indicates seepage; note also red tones shows early vegetation growth near seepage.

Station 14: Manure and leaf piles, with dark seepage from base of pile.

Station 19: Dark (greenish) tone indicates seepage at toe of short incline; note similarity with runoff colour at Station 7.

Station 22: Runoff or leachate seepage and runoff gully?

c) Thermography

High water contents at the Bayview landfill complicated thermal patterns in the spring imagery. Level-slicing was used to enhance warmer leachate outbreaks. Observations were made at the following station locations.

Stations 10, 11, 12: Extremely warm signatures (bright) appear to form the head of a drainage pattern which flows outward from the edge of the landfill. The warm influence of

these discharges appears to last for some distance resulting in an elongation of the signature. These may identify active leachate springs.

d) Field Observations

A field visit was made in early June 1980. At this time, the entire site was traversed and a number of observations made. These observations are described as follows:

Station 10: A line of cattails on landfill slope identify leachate seepage zone and leachate spring; drains down slope, into cattail wetland; spring is clear with some scum and strong odour: 5 ± gpm flow: conductivity 6000 ± us; temperature 13°C.

Station 11: No evidence of seepage activity observed.

Station 12: Leachate spring at toe of landfill; several small seeps associated; main spring has 5 ± gpm flow, clear with strong odour.

Station 13: Small leachate seeps in grass above road.

Station 14: Leaves and manure dumped at the top of the landfill slope. Seepage from piles oozing down slope.

Station 15: Abandoned test pit; water to surface.

Station 16: Cool area on March thermography and light area on April photography is broken concrete.

Station 17: Runoff gully; no evidence of leachate seepage along runoff channel on site.

Station 20: Stream east of King Road; staining; faint leachate odour; conductivity 2000 ± us.

Station 21: Several leachate springs along toe of landfill feed small stream; conductivity 6000 ± us; flow 5 ± gpm; heavy vegetation cover.

## 4.4 Summer Data

### 4.4.1 Sensing Conditions

The late July photography provided the only opportunity to examine vegetation stress on and around this site. Some natural stress is occurring in grasses and crops due to summer drought. However, tree canopy and ground cover in depressions or wet areas are still vigorous. Weather data prior to 25 July 1980 are listed in Figure D.6.

Summer thermography of the Bayview Park is unavailable due to the emergency use of the thermal line-scanner for forest fire mapping. However, thermography is least effective in detecting seepage during the summer season.

### 4.4.2 Diagnostic Features

a) Colour

Indicators of leachate seepage on the summer colour photography are indirect and somewhat inconclusive. Vegetation gaps and dead ground cover can be attributed to natural or landfill unrelated features. Areas of vigorous grass cover may indicate local seepage (increased moisture) but there is no other evidence to support leachate discharge.

Cattail marshes along channels south of the site are clearly visible. Their development suggests a constant source of moisture from the landfill.

Detailed observations below are located on Figure D.9.

Station 25: Patches of healthier grass among areas of brown grass may indicate very slow seepage on the landfill.

Station 28: Gaps in ground cover on these steep slopes due to erosion; bare soil shows no indication of seepage.

Station 32: Area of dead grass downslope from leaf-manure piles; there is possible seepage and grass kill due to leachate occuring in this area.

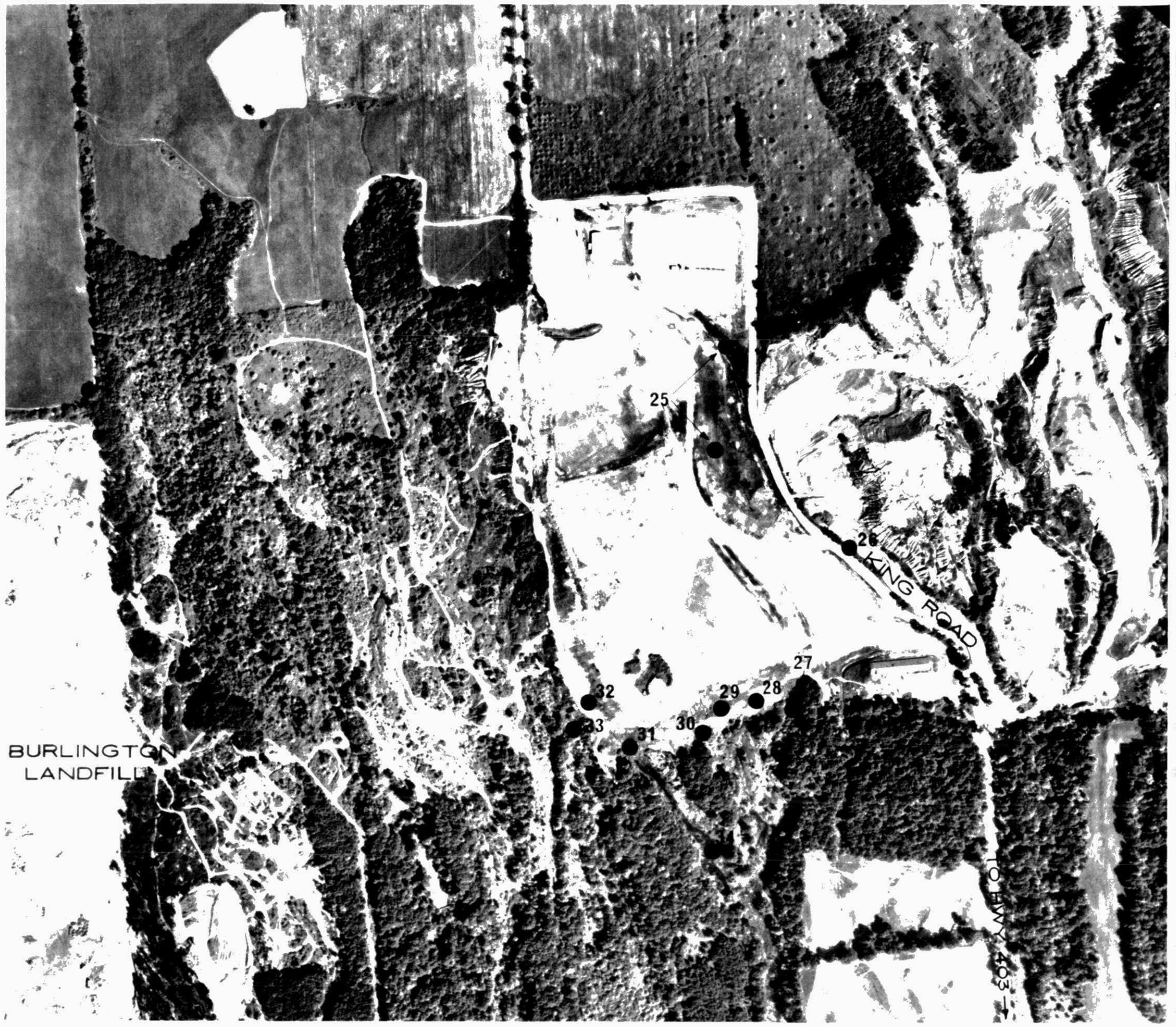
Station 33: Gap in trees at spring; visible as grey tone.

Station 34: Cattail wetlands.

b) Colour Infrared

A line of healthy vegetation (red tone) on the south landfill slope, visible on the colour infrared film, identifies a leachate seepage zone. Less conclusive of leachate seepage are scattered areas of vigorous grass cover within the generally droughty site. Negative vegetation stress in trees around the site perimeter is inconclusive - scattered stress also occurs naturally in tress beyond the landfill influence area.

Cattail wetlands south of the site are clearly visible. Their development suggest a fairly constant supply of moisture from the landfill.




Ministry of the Environment
Ontario

Bayview Park Site

# D·9 Summer data
(July 1980)

●30 SAMPLING NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHS
PANCHROMATIC PRINT – BRS80-36
COLOUR INFRARED PRINT – BRS80-37

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
(Consultant)
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

The observations below are located on Figure D.9.

Station 25: Variable vegetation stress in poplars along King Road.

Stations 27 to 29: Possible vegetation stress along south end of landfill; indeterminant feature.

Station 31: Cattails marking line of leachate seepage clearly show as healthy red tone against stressed grey pink toned grass (summer drought).

Station 32: Area of dead grass cover shows as grey green tone. Less contrast with surrounding cover than on colour photography; seepage visible; note clarity of wetness near manure/leaf piles.

Station 33: Vegetation gap at spring clearly visible amongst healthy red vegetation.

Station 34: Wetlands.

c) Field Observations

Leachate seepage identified in the spring was confirmed during the 6 August 1980 field visit. No vegetation stress was visible in trees along the perimeter of the site.

The observations below are located on Figure D.9.

Station 30: Small leachate seep in runoff gully.

Stations 31, 33: Leachate springs; (see Spring field data).

Station 32: Several leachate seeps, mixed with seepage from manure-leaf piles occur along here; grass cover has been killed in some places; however, leachate seeps in patches of healthy ground cover were obscured by the grass even during field checking; in these areas, vegetation kill was restricted to the leachate flow path.

## 4.5 Autumn Data

### 4.5.1 Sensing Conditions

Photography, at 1:6000 scale, and thermography were obtained in late November 1980. Deciduous trees are leafless and the snow that covered the ground during the 18 November 1980 field visit had melted, providing good conditions for photographic interpretation. Sensing conditions were excellent for thermography. Cold nighttime temperatures provide a thermally flat background and good temperature contrasts for detecting springs. Weather data prior to 27 November 1980 are listed in Figure D.6.

### 4.5.2 Diagnostic Features

a) Colour

Areas of dead grass and red-brown zones caused by possible leachate staining identify landfill related seepage areas on the autumn colour photography. However, photographic indicators are very indistinct in the vicinity of the main leachate springs.

The observations below are located on Figure D.10.

Station 36: Dead grass occurs downslope of manure leaf piles.

Station 37: Small area of dead grass occurs where leachate seepage was observed in summer.

Station 43: Brown tone on grass may be leachate staining; indistinct indicator.

b) Colour Infrared

Leachate seepage is indicated by dead grass areas and at one station by visible seepage (dark tone). Scattered areas of healthy grass still persist suggesting possible moisture and warmth from very slow leachate discharge.

Neither of the major leachate springs is detected on the colour infrared film.

The observations below are located on Figure D.10.

Stations 36, 37: Dead grass areas (blue to blue-green tones) at leachate seepage.

Station 43: Leachate seep visible (blue tone just below pink toned grass cover).

Station 44: Scattered zones of persisting healthy grass (reddish tones) may indicate seepage or warmth from landfill. Some correlate to summer Station 25.

c) Thermography

The autumn thermography produced poor data despite the excellent sensing conditions. Analog imagery was very flat and even level-slicing techniques failed to clearly enhance thermal anomalies. In addition, the imagery is "noisy", particularly in the southern area of the landfill; this is due to mechanical problems during acquisition.

The four thermal anomalies identified are briefly described below and are located on Figure D.10.

Station 35: Warm anomaly indicates seepage area; probably uncontaminated discharge.

Station 39: Warm anomaly indicates seepage; not observed in field.

Station 41: Warm anomaly indicates surface ponding on site; probably uncontaminated runoff; not observed in field.

Station 42: Warm anomaly along runoff channel suggests leachate seepage.

Station 45: Warm anomaly; possible leachate seepage; not observed during 1980, but recroded during Spring 1981 in field.

d) Field Observations

Leachate discharge locations were confirmed during the 18 November 1980 field visit. Observations listed below are located on Figure D.10.

Ministry of the Environment
Ontario

# D·10 Autumn data
## ( Nov. 1980 )

●35 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:6000)
COLOUR PRINTS
– GRS80164-24
COLOUR INFRARED PRINT
– GPS80163-23

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
and
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Station 36: Leachate seeps and drainage from manure piles have killed some vegetation cover.

Station 37: Leachate seepage; several small seeps less than .3 m wide.

Station 38, 40: Vigorous leachate springs; (see Spring field data for description).

Station 42: Possible leachate seepage (very slow discharge) is occurring periodically in the runoff channel; no particular discreet seepage point observed.

Station 43: Leachate seepage from slope; very little discharge; some faint red-brown staining and minor grass kill.

## 5. ANALYSIS

### 5.1 Archival Data

Stereoscopic interpretation of the archival photography provides a sequential picture of landfill development and allows the observer to predict areas of impact.

The smooth refuse mound visible in the 1978 photography is a topographic anomaly within the gullied bedrock terrain. This topographic form allows it to be easily identified as a landfill, illustrating the use of panchromatic photography as a technique in identifying closed landfills within this type of terrain.

When the 1954 photographs are compared with the 1978 prints, the observer can see the location of the original bedrock gullies which have subsequently been in-filled by the landfill. These buried drainage channels form natural paths along which leachate can migrate. Thus, the archival photography provides us with a predictive tool for locating future possible leachate springs.

### 5.2 Photographic Indicators - 1980

The key photographic indicators that appear to be useful in identifying landfill activites at the Bayview Park site are:

1) Vegetation effects
2) Seepage
3) Snow gaps

Field verification showed that these features were often indicative of leachate discharge. However, such indicators

require field verification and their effectiveness depends upon many factors including both site conditions and imagery clarity.

a) Vegetation Effects

Anomalies in vegetation growth on the landfill - more vigorous growth or areas of dead ground cover - are common indicators of leachate discharge.

Areas of positive stress (healthy vegetation) occur where leachate seepage encourages growth. A leachate discharge zone on the south slope of the site is identified by a thin line of vigorous vegetation visible on the summer colour infrared film. The vegetation (cattails) has a dark red tone that contrasts sharply with the surrounding pinkish tone of the dry ground cover. The location of the vegetation - mid-slope on the south or "downstream" side of the landfill - and its comparative vigor due to moisture supply are fairly strong indicators of leachate seepage. Similar positive stress is observed where early spring vegetation growth (red tone on colour infrared) is detected around a seepage area. However, the areas of healthy grass (green on colour film; red on colour infrared film) observed on the site in summer and autumn are less conclusive indicators of leachate seepage. While moisture from slow leachate seepage could be locally enhancing grass growth, other environmental factors, including watering by riding school operators, could also be creating this effect.

An area of dead grass on the southwest part of the site is associated with several small leachate seeps. The grass kill is visible on all photography, and seepage associated with the grass kill is visible on the colour infrared and spring colour photographs. However, this ground cover kill

and seepage could be attributed by photographic interpretation to runoff from manure and leaf piles dumped at the top of the landfill slope. In fact, field checking indicates that the upper part of the vegetation kill is due to this; leachate seeps appear to discharge from halfway down the slope.

Negative stress in trees and ground cover around the site perimeter is inconclusive. Gaps exposing bare soil on the site cover are due to erosion and poor revegetation. A leachate spring at the landfill toe has created a gap in the tree cover. This is visible on the summer infrared film but is not a unique feature.

b) Seepage

Dark tones indicating soil wetness are usually associated with dead grass areas and they identify leachate seepage on top of the landfill. Soil wetness is best detected by the colour infrared film although seepage is visible on the spring colour photographs. Seepage from manure piles, however, is identical to leachate seepage.

c) Snow Gaps

Gaps in snow cover appearing at the south toe of the landfill on the March colour photographs identify active leachate seepage. One gap has a "stream-like" appearance, caused by leachate draining down the landfill face into wetlands. This is among the best indicators of the two vigorous leachate springs on the southwest corner of the site.

d) Staining

Red-brown staining of snow cover appears to be caused by surface runoff from the red-brown soils rather than being an indicator of leachate discharge.

5.3 Thermography

The key indicators of leachate outbreak - as observed on the thermography - are signature brightness (warmth) and signature shape (thermal influence). These signatures are caused by thermal contrasts created, for example, when ground water seepage during the winter is warmer than the ground surface.

Field checking of the thermal anomalies showed that they were caused by a number of conditions, including ground water seepage, leachate seepage, and rapid stream flow. One anomaly was identified with no obvious cause found in the field.

On the March imagery, the leachate discharge areas appear as very bright, discrete points, and level-sliced imagery shows three such outbreaks. This same imagery, however, show two other anomalies on the east and west of the landfill that did not appear to be leachate contaminated.

The anomalies identified on the April thermography are less distinct and have poorer contrasts. This is caused by the lower thermal contrast conditions prevalent in April as compared to early March.

Anomalies on the November imagery are only visible after level-slicing. There was some background noise which interferes with analysis, but basically the thermal contrasts seem to be lacking as they relate to landfill seepage.

At the other end of the thermal scale and as a point of interest, on the November thermography a very cold (dark) thermal anomaly is seen perpendicular to the road on the east. Ground checks showed an abandoned covered tunnel entrance which formerly joined the shale pits on the east side of the road to the original shale pits on the landfill site.

## 5.4 Sensor Evaluation

Archival photography is the most cost effective of the sensors evaluated. The photographs - dating from 1942 to 1978 - provide good information on the extent of landfilling and the original geological conditions. From this information, interpreters are able to accurately predict the main leachate seepage zone along the southern part of Bayview Park landfill.

With regard to the 1980 photography, colour and colour infrared detected about the same proportion of seepage during the different seasons (Figure D.11). The highest coverage level was obtained during spring - although the proportion of discharge detected is not significantly greater. Generally, indicators were duplicated on both sensors although occasionally a single feature might be seen on one film and not on the other.

Despite the vegetation cover on the site and around the landfill perimeter, colour infrared film did not have a major

FIGURE D.11

1980 SENSOR EVALUATION

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Late Winter | | | | |
| 1 | Leachate spring | Y | Y | Y |
| 2 | Leachate spring | Y | Y | Y |
| 3 | (not found) | N | N | I(spring) |
| 4 | Leachate seep | N | N | Y |
| 5 | Runoff gully | Y | Y | N |
| 6 | Not recorded | I | N | N |
| 7 | Leachate seep | N | I | Y |
| 8 | Tunnel under road | N | N | cold anomaly |
| 9 | Not recorded | N | N | Y(spring) |
| 9A | Not recorded | N | N | Y(spring) |
| Spring | | | | |
| 10 | Leachate spring | N | N | Y |
| 11 | (not found) | N | N | Y |
| 12 | Leachate spring | Y | I | Y |
| 13 | Leachate seeps | Y | Y | N |
| 14 | Manure seeps | Y | Y | N |
| 15 | Test pit | Y | Y | N |
| 16 | Broken concrete | Y | Y | N |
| 17 | Runoff gully | I | I | N |
| 18 | Not recorded | I | N | N |
| 19 | Not recorded | I(seep) | I(seep) | N |
| 20 | Contaminated stream | N | N | N |
| 21 | Leachate spring | N | N | N |
| 22 | Runoff gully | I | I | N |
| 23 | Leachate seep | N | N | N |
| 24 | Wetlands | Y | Y | N |
| Summer | | | | |
| 25 | Vegetation | I | I | |
| 26 | Vegetation | N | I | |
| 27 | Vegetation | N | I | |
| 28 | Vegetation | I | I | |
| 29 | Vegetation | N | I | |
| 30 | Leachate seep | N | N | |
| 31 | Leachate spring | N | Y | |
| 32 | Leachate seeps | I | Y | |
| 33 | Leachate spring | I | I | |
| 34 | Wetlands | Y | Y | |

FIGURE D.11

1980 SENSOR EVALUATION

(continued)

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Autumn | | | | |
| 35 | Not recorded | N | N | I(spring) |
| 36 | Leachate seep | I | I | N |
| 37 | Leachate seep | I | I | N |
| 38 | Leachate spring | N | N | N |
| 39 | Not observed | N | N | I(seep) |
| 40 | Leachate spring | N | N | N |
| 41 | Not observed | N | N | I(pond) |
| 42 | Leachate seep | N | N | I |
| 43 | Leachate seep | I | Y | N |

Y - feature identified
N - not identified
I - inconclusive or indistinct

advantage over colour. While indicators were clearer generally on the colour infrared film, this was not a consistent occurrence - individual features including staining and vegetation gaps might be clearer on the colour photographs during particular season. In fact, snow gaps, detected in March, were more distinct on the colour film.

The photography is best suited to detecting the small seeps on the landfill surface. The more vigorous leachate discharge at the landfill toe is less visible, and as a result, photographic indicators are less conclusive. While two toe springs are located on the March photography and the July infrared film, numerous springs are consistently undetected because of heavy tree cover. Thermography also failed to detect numerous leachate springs. Best results were obtained in March (Figure D.11), when thermal contrasts were at their maximum.

All thermography data must be field checked since the imagery does not discriminate between landfill related and other thermal anomalies. In addition, background reference points are lost during level-slicing of data. Although enchancing the anomalies, the level-slicing makes it difficult to accurately relate the feature to a location on the ground. This may explain the poor detection performance of the November imagery - the lack of reference background locations may have caused incorrect location of the anomalies on the map.

No single sensor records all leachate discharge areas at Bayview Park landfill. It is possible to identify the major proportion of leachate seeps, but there is a consistent failure to identify seepage areas under the tree canopy. On the other hand, interpretation of the archival photography is successful in predicting the main area of leachate seepage, and even probably locations of concentrated leachate discharge.

## 6. CONCLUSIONS

The archival photography appears to be the single most useful sensor at the Bayview Park site. Interpretation of existing photographs identifies the landfill extent and main leachate discharge areas. In addition, these data are useful in design of remedial measures at the landfill.

The 1980 imagery identified most of the active leachate discharges. Small seeps on the top landfill surface were better detected than the more vigorous seeps on the landfill toe. However, none of the indicators are unique and all observations had to be field checked to ascertain the leachate discharge.

## 7. IMAGERY USED AT THE BAYVIEW PARK SITE

### 7.1 Archival

Archival photographs used at this site are:

| YEAR | SCALE | PHOTO NUMBER | SOURCE |
|---|---|---|---|
| 1942 | 1:10000 | 673 # 45-47 | N.A.P.L. |
| 1950 | 1:9600 | A12511 # 21-24, 69-72 | N.A.P.L. |
| 1954 | 1:15840 | 4315-26 # 94-95 | M.N.R. |
| 1965 | 1:16000 | A19343 # 30-32 | N.A.P.L. |
| 1972 | 1:15840 | 4314-23 # 30-31 | M.N.R. |

### 7.2 1980 Imagery

Figure D.4 shows the area covered by the 1980 imagery. Scale, date and target photographs are given for each imagery set.

### 7.3 Sources

A complete set of imagery is available for viewing at the following offices of the Ontario Ministry of the Environment:

Solid Waste Unit
Waste Management Branch
Ontario Ministry of the Environment
4375 Chesswood Drive
Downsview, Ontario
M3J 2C2

Central Region
Ontario Ministry of the Environment
Suite 700
150 Ferrand Drive
Don Mills, Ontario
M3C 3C3

Copies of imagery may be obtained from:

1980 Imagery - Contact Ministry of the Environment offices.

Archival:

N.A.P.L.: National Air Photo Library
Energy Mines and Resources
625 Booth Street
Ottawa, Ontario
K1A 0E9
Telephone: (613) 995-4560

M.N.R.: Public Service Centre
Ontario Ministry of Natural Resources
Whitney Block
Queen's Park
Toronto, Ontario
M7A 1W3
Telephone: (416) 965-1123

# Appendix E
# Burlington site

## Remote Sensing Techniques & Waste Management Assessments

# 1. INTRODUCTION

The Burlington landfill is located immediately north of Highway 403, just west of its junction with the Q.E.W. (Figure E.1). It is one of six southern Ontario landfills used in the study "Remote Sensing Techniques and Waste Management Assessment", prepared for the Ontario Ministry of the Environment. The study purpose is to evaluate specific remote sensing techniques for application to landfill monitoring and identification.

Colour and colour infrared aerial photography, and thermography was acquired during 1980. This imagery, along with archival photography was interpreted for application in monitoring and identifying existing landfill sites. A summary of the results, comparative evaluation of techniques and final study conclusions are presented in Volume 1 of this report.

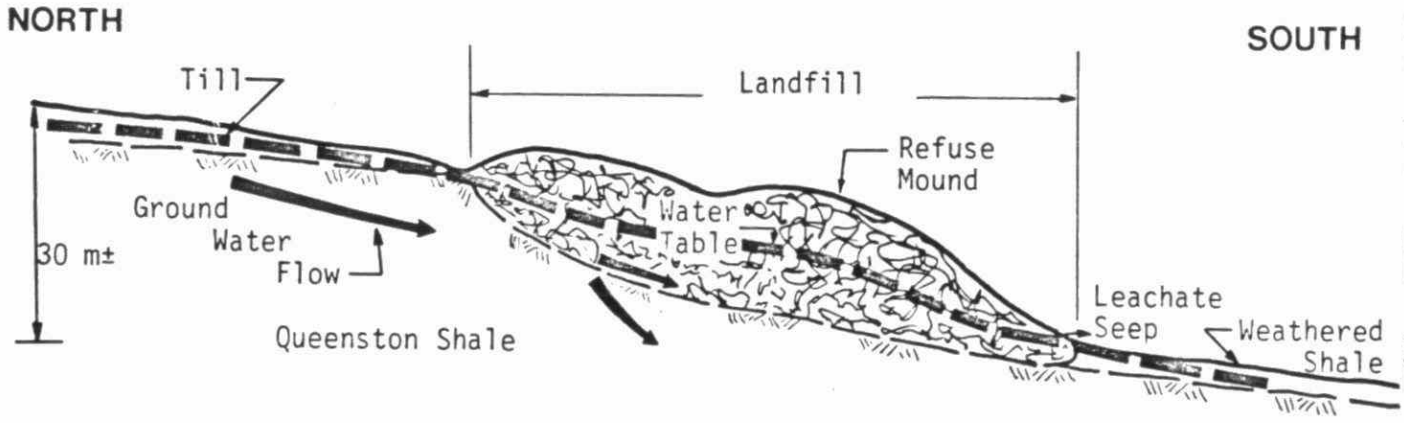
This appendix contains the detailed results for the Burlington site only. The appendix is one of six similar appendices comprising Volume 2. Together they provide all the detailed accumulated observations and data accumulated during this study. Each appendix is designed to be used separately with Volume 1, (the general text) if desired.

## 2. BACKGROUND

### 2.1 Physical Setting

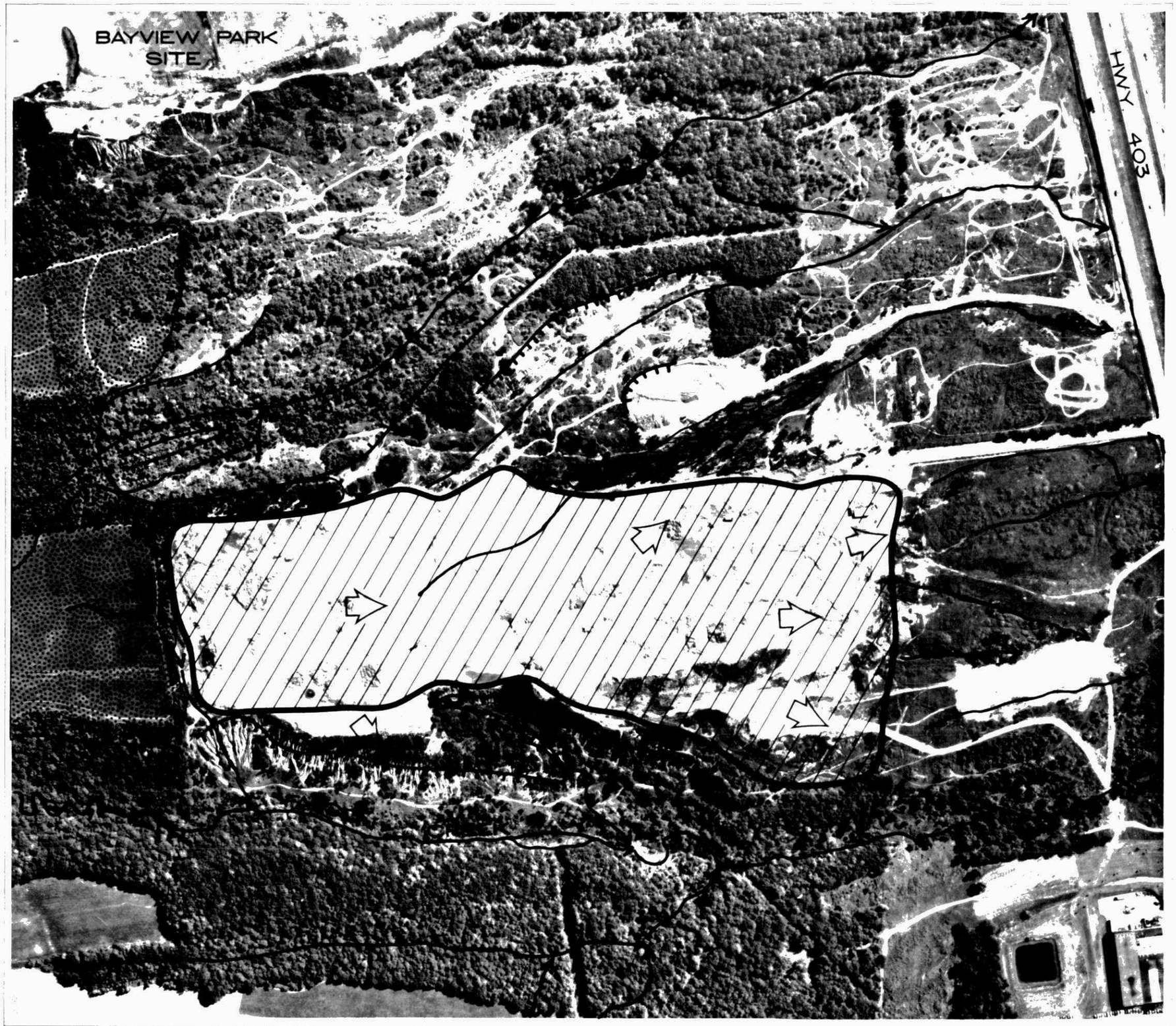
The Burlington Landfill is developed in an eroded shale bedrock environment on the lower slope of the Niagara Escarpment (Figures E.2, E.3). The site was a former shale pit developed along intermittent runoff gullies. Refuse is placed directly on the Queenston Shale, filling the pit and gullies, and creating a north-south sloping mound in the bedrock terrain (sketch below). The western side of the landfill is bounded by the deep bedrock valley of Falcon Creek; several smaller ravines, extensions of the original drainage border the east side of the landfill.

Schematic Cross Section of Burlington Landfill




The Queenston Shale - which underlies the entire area - has an upper weathered zone of soft, red brown clayey silt. Near

BURLINGTON
Waterdown
BURLINGTON
HAMILTON
OAKVILLE
MILTON
BRAMPTON
GEORGETOWN
TORONTO
MARKHAM
AURORA
NEWMARKET
OSHAWA
WHITBY
AJAX
PETERBOROUGH
COBOURG
Port Hope
Bowmanville
Newcastle
Port Perry
Uxbridge
Stouffville
Richmond Hill
Woodbridge
Maple
Kleinburg
Bolton
Caledon
Caledon East
Palgrave
Schomberg
Tottenham
Beeton
Bradford
Holland Landing
Queensville
Keswick
Sutton
Stroud
Orillia
Lindsay
Peterborough
Cobourg
Brighton
Trenton
Napanee
Belleville
Picton
Oshawa
Whitby
Ajax
Pickering
Scarborough
Toronto
Mississauga
Brampton
Georgetown
Milton
Oakville
Burlington
Hamilton
Grimsby
St Catharines
Niagara Falls
Niagara-on-the-Lake
Welland
Fonthill
Lincoln
Caledonia
Smithville
Jordan
Vineland
Port Dalhousie
Queenston
Lewiston
North Tonawanda
Beach Ridge
Virgil
Winona
Mount Hope
Binbrook
Caistorville
Lake Ontario
Lake Simcoe
Scugog Island
Seagrave
Manilla
Little Britain
Oakwood
Reaboro
Omemee
Mount Pleasant
Millbrook
Cavan
Bailieboro
Harwood
Cores Landing
Cold Springs
Bewdley
Pontypool
Blackstock
Caesarea
Greenbank
Udora
Leaskdale
Sunderland
Jackson's Point
Willow Beach
Roches Point
Thornton
Borden
Alliston
Cookstown
Everett
Lefroy
Queensville
Mount Albert
Holland Landing
Bradford
Beeton
Tottenham
Schomberg
Aurora
Newmarket
Whitchurch-Stouffville
Oak Ridges
King City
Nobleton
Bolton
Caledon East
Palgrave
Mono Mills
Claremont
Brougham
Markham
Brooklin
Whitby
Ajax
Gold Point
Thickson's Point
Richardson Point
Raby Head
Bowmanville
Newcastle
Orono
Hampton
Tyrone
Enniskillen
Kendal
Port Hope
Newtonville
Crysler Point
Bouchette Point
Otty Point
Lucas Point
Chub Point
Colborne
Grafton
Baltimore
Cold Springs
Bewdley
Millbrook
Bailieboro
Harwood
Cores Landing
Pontypool
Blackstock
Caesarea
Scugog Island
Port Perry
Uxbridge
Greenbank
Udora
Leaskdale
Sunderland
Seagrave
Manilla
Little Britain
Oakwood
Reaboro
Omemee
Mount Pleasant
Peterborough
Keene
Roseneath
Warkworth
Hastings
Castleton
Jackson's Point
Willow Beach
Sutton
Roches Point
Keswick
Queensville
Mount Albert
Holland Landing
Bradford
Cookstown
Alliston
Everett
Borden
Stroud
Lefroy
Thornton
Beeton
Tottenham
Schomberg
Newmarket
Aurora
Whitchurch-Stouffville
Oak Ridges
King City
Nobleton
Bolton
Caledon East
Caledon
Palgrave
Mono Mills
Claremont
Brougham
Markham
Brooklin
Whitby
Ajax
Gold Point
Thickson's Point
Richardson Point
Raby Head
Bowmanville
Newcastle
Orono
Hampton
Tyrone
Enniskillen
Kendal
Port Hope
Newtonville
Crysler Point
Bouchette Point
Otty Point
Lucas Point
Chub Point
Colborne
Grafton
Baltimore
Cold Springs
Bewdley
Millbrook
Bailieboro
Harwood
Cores Landing
Pontypool
Blackstock
Caesarea
Scugog Island
Port Perry
Uxbridge
Greenbank
Udora
Leaskdale
Sunderland
Seagrave
Manilla
Little Britain
Oakwood
Reaboro
Omemee
Mount Pleasant
Peterborough
Keene
Roseneath
Warkworth
Hastings
Castleton
1065
940
990
1090
820
915
613
1180
1265
1340
1315
1215
1265
1015
44
760
1190
1538
500
865
Woodbridge
Maple
Kleinburg
Bolton
Caledon
Caledon East
Palgrave
Mono Mills
Nobleton
Markham
Oak Ridges
King City
Aurora
Newmarket
Whitchurch-Stouffville
Claremont
Brougham
Brooklin
Whitby
Ajax
Oshawa
Bowmanville
Newcastle
Port Hope
Cobourg
Peterborough
Millbrook
Bailieboro
Harwood
Cores Landing
Cold Springs
Bewdley
Pontypool
Blackstock
Caesarea
Scugog Island
Port Perry
Uxbridge
Greenbank
Udora
Leaskdale
Sunderland
Seagrave
Manilla
Little Britain
Oakwood
Reaboro
Omemee
Mount Pleasant




Ministry of the Environment
Ontario

# E·2 Physical setting

EXTENT OF LANDFILL (NOV 1980)

BEDROCK TERRAIN

SHALLOW CLAYEY SILT TILL

WETLAND

STEEP BEDROCK SCARP

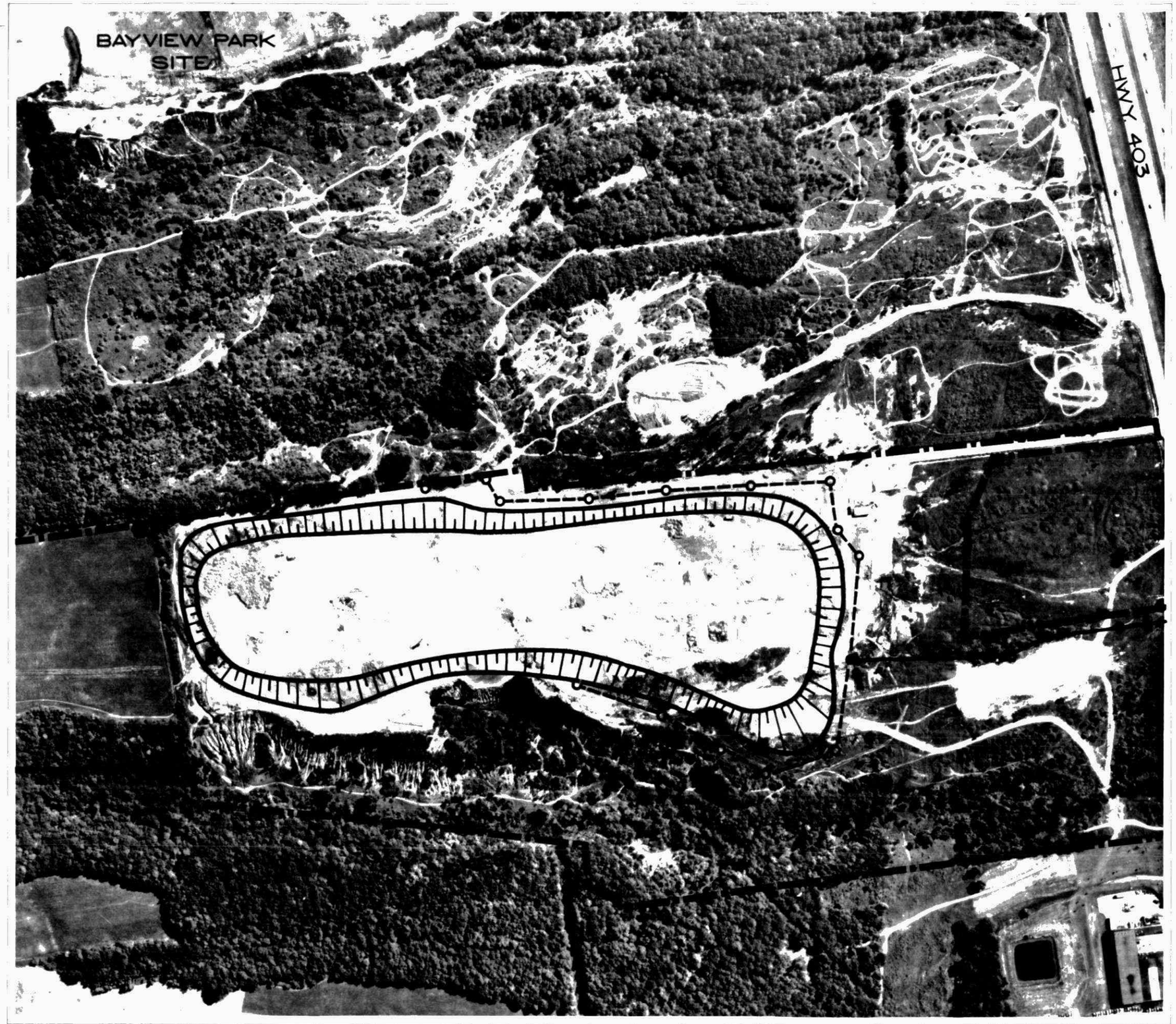
SURFACE DRAINAGE COURSE

GENERAL DIRECTION OF GROUND WATER FLOW

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED

[illegible]
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES




Ministry of the Environment
Ontario

# E·3 Site plan

PROPERTY BOUNDARY

LANDFILL LANDFORM SIDE SLOPES

LEACHATE COLLECTION SYSTEM

TOEDRAIN LEACHATE COLLECTOR

LEACHATE TRANSMISSION SEWER

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

the landfill, the shale is covered by a thin deposit of clayey silt till. This till layer becomes thicker north of the site. Bedrock is frequently exposed along the ravines.

Leachate springs discharge around the perimeter of the Burlington site. Ground water flows south to southeastward through the refuse, following the bedrock slope and original surface drainage directions (Figure E.5). As a result, most active springs are located along the southern and southeastern edge of the landfill. Springs on the landfill face or near the north end of the landfill probably result from perched leachate conditions; investigations show that ground water has not mounded significantly in the refuse. Leachate also flows down into the fractured shale bedrock; it then moves southward, following the direction of regional ground water flow. Leachate seepage has been recorded along Falcon Creek, adjacent to the landfill. A toe drain was installed in 1980 to intercept seepage along the east, south and west sides of the landfill.

Surface drainage flows into two micro watersheds - directly into Falcon Creek west of the site and into unnamed tributaries of Falcon Creek on the east side. Falcon Creek is a perennial stream, although it may have very little flow for periods during the summer. The unnamed tributaries are intermittent runoff channels. The cattail wetland has developed along the more southerly tributary.

## 2.2 Site History

In operation since 1972, the Burlington Landfill Site is run by private contractor. In 1972 and 1973 the site was

operated by the contractor for the City of Burlington after which the contractor was responsible to the Regional Municipality of Halton. The initial site area of 20 hectares was expanded by 1975 to its present size of 39 hectares.

The area of the Burlington landfill site had been used for shale extraction for use in brick manufacture since at least the 1940's. With its shallow overburden thickness and deep ravines and gullies, easy access to shale material was available at a number of of working faces. A large eroded area in the Falcon Creek ravine still remains as evidence of past operations.

In 1971 approval to develop the site was obtained and in 1972 landfilling began. Operations were carried out by private contractor using two bulldozers until 1975 and with a landfill compactor and a crawler loader since then.

The current operations comprise the landfilling of 100,000 tonnes of refuse per year. Wastes are generated within the City of Burlington from residential, commercial, industrial and construction/demolition operations. Daily operations consist of waste compaction and covering with primarily clay tills. A large part of the site has been covered and graded. In particular extensive final grading and final covering were carried out in 1979 and 1980.

Leachate was noted on site on the east and south sides in 1976 and in the southwest area in 1977. In 1979 a toe drain leachate collection system was installed in the south part of the site. The system drains leachate off-site to the municipal sanitary sewer system. In the area where the leachate collector system has been installed, surface leachate discharge has been controlled.

To further control the surface breakout of leachate, the collector system is being extended along the west side of the northern part of the site.

## 3.0 METHODOLOGY

The prime objective of the study was to evaluate remote sensing techniques for thier applicability to waste management programs. Six sites were selected for the study and a program for acquisition of remote sensing data for the sites was developed.

Four remote sensors were selected for the study:

i) colour aerial photography
ii) colour infrared aerial photography
iii) aerial thermography
iv) archival photography

Each sensor was expected to be capable of providing specific data on the condition of each site - in particular the discharge of leachate (colour aerial photography and aerial thermography). The sites selected represented a range of differing hydrogeological conditions, with a known history of surface discharge of leachate, and with various stages of site operation and site rehabilitation.

The selected sites were:

Cobourg Landfill Site
Whitby Landfill Site
Oakville Landfill Site
Bayview Park Landfill Site (in Burlington)
Burlington Landfill Site
Upper Ottawa Street Landfill Site -
(in Hamilton)

The program for evaluation of sensors comprised initially the acquisition and review of hydrogeological assessments made

for the site through previous studies. In addition, to assist in providing an understanding of site history and past operations, archival photography was obtained dating back to pre-landfill period (1954) and taken at intervals ranging from 5 to 7 years to present. To further assist in constructing a site development history, a review of Ministry files for the site was made. Observations of site operations and leachate discharge were reported and give insight on the development of leachate mounding and on operational procedures which have conributed to present site conditions.

The schedule for remote sensing data acquisition was:

| Sensor | Flight Date | Field Reconnaissance |
|---|---|---|
| colour photography | 12 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 17 June 1980<br>6 August 1980<br>17 November 1980 |
| colour infrared photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 17 June 1980<br>6 August 1980<br>17 November 1980 |
| thermography | 4 March 1980<br>17 April 1980<br>26 November 1980 | 17 June 1980<br>6 August 1980<br>17 November 1980 |

Photography scale was changed from 1:8000 for March and April flights to 1:6000 for July and November flights. Average flying altitude for thermography was 1050 m, giving an approximate scale of 1:14000. Data acquisition details are given on Figure E.4.

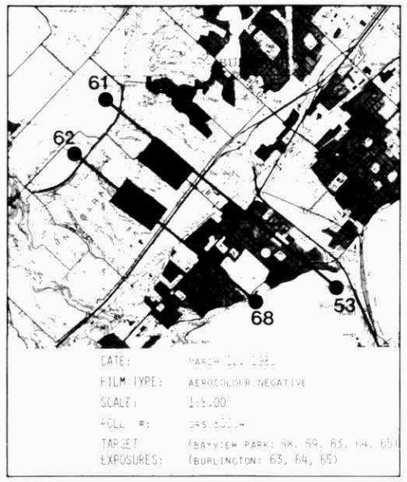
After each flight, photography and imagery were examined and preliminary interpretations made. Detailed field reconnaissance was made to confirm interpretations and to identify features undetected on the sensor data. Photography

and imagery for each flight were annotated and annotations for subsequent flights compared so that assessment of the relative effectiveness of sensors under varying seasonal conditions would be made.

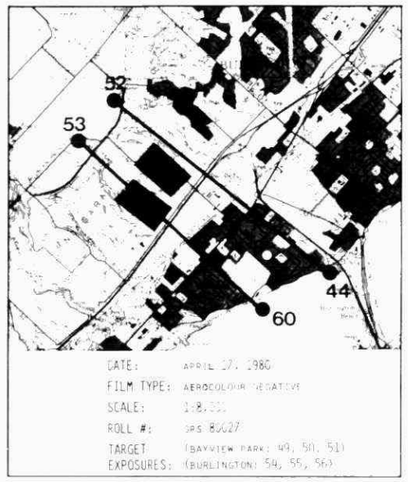
Following completion of all data acquisition, interpretations and field work, comparative assessments of data with respect to season, sensor type, and type and extent of features sensed were made. Site features detectable in the field were noted and compared to those interpreted from photography and imagery. These records and interpretations were used as a basis for determining the effectiveness of each technique.

The relative merits of the various sensors in satisfying the study objective and taking into account relative costs of data acquisition were then assessed.

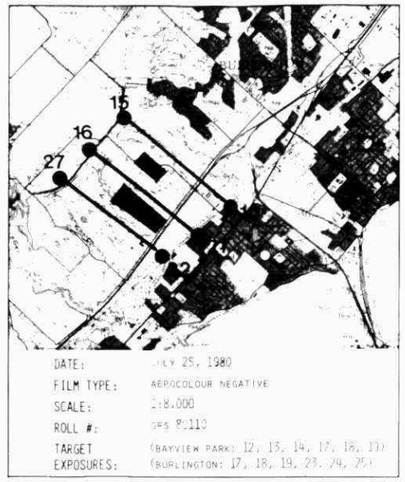
TRUE COLOUR



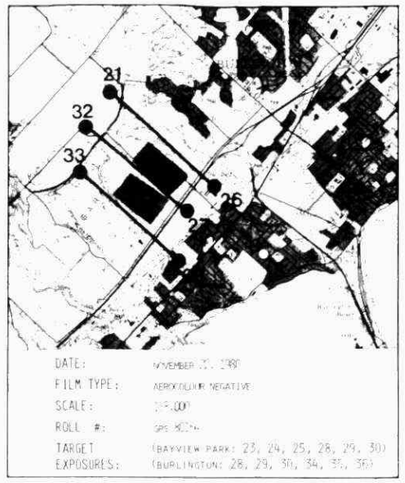

DATE: MARCH 21, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: SAS 80027
TARGET EXPOSURES: (BAYVIEW PARK: 64, 65, 66, 67, 68) (BURLINGTON: 63, 64, 65)




DATE: APRIL 27, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: SAS 80027
TARGET EXPOSURES: (BAYVIEW PARK: 49, 50, 51) (BURLINGTON: 54, 55, 56)

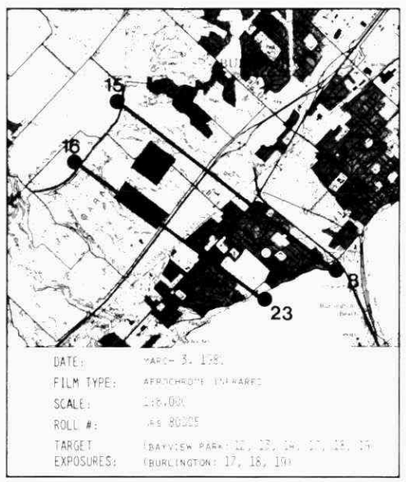



DATE: JULY 25, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: SAS 80110
TARGET EXPOSURES: (BAYVIEW PARK: 12, 13, 14, 17, 18, 19) (BURLINGTON: 17, 18, 19, 23, 24, 25)

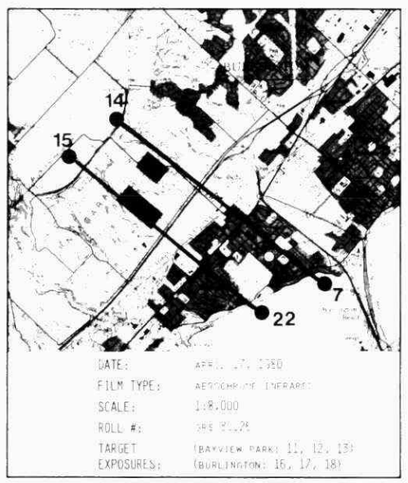



DATE: NOVEMBER 20, 1980
FILM TYPE: AEROCOLOUR NEGATIVE
SCALE: 1:8,000
ROLL #: SAS 80214
TARGET EXPOSURES: (BAYVIEW PARK: 23, 24, 25, 28, 29, 30) (BURLINGTON: 28, 29, 30, 34, 35, 36)

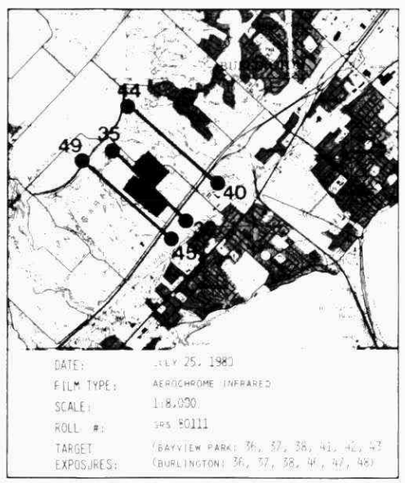
COLOUR INFRARED



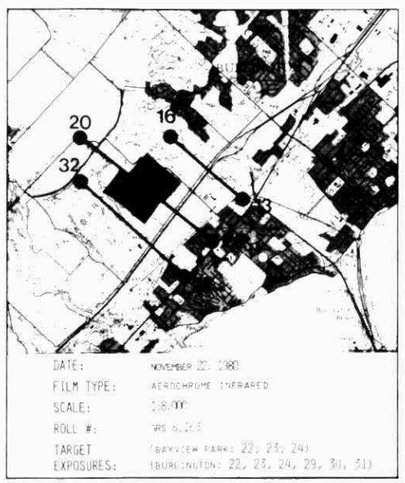

DATE: MARCH 3, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: SAS 80025
TARGET EXPOSURES: (BAYVIEW PARK: 12, 13, 14, 17, 18, 19) (BURLINGTON: 17, 18, 19)




DATE: APRIL 27, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: SAS 80028
TARGET EXPOSURES: (BAYVIEW PARK: 11, 12, 13) (BURLINGTON: 16, 17, 18)




DATE: JULY 25, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: SAS 80111
TARGET EXPOSURES: (BAYVIEW PARK: 36, 37, 38, 41, 42, 47) (BURLINGTON: 36, 37, 38, 41, 42, 46)




DATE: NOVEMBER 20, 1980
FILM TYPE: AEROCHROME INFRARED
SCALE: 1:8,000
ROLL #: SAS 80215
TARGET EXPOSURES: (BAYVIEW PARK: 22, 23, 24) (BURLINGTON: 22, 23, 24, 29, 30, 31)

THERMOGRAPHY

DATE: MARCH 10, 1980
SENSOR: THERMOGRAPH
CONDITIONS: PRE DAWN

DATE: APRIL 27, 1980
SENSOR: THERMOGRAPH
CONDITIONS: PRE-DAWN

DATE: NOVEMBER 21, 1980
SENSOR: THERMOGRAPH
CONDITIONS: PRE DAWN

LATE WINTER | SPRING | SUMMER | AUTUMN

Ministry of the Environment
Ontario

# Burlington site

# E·4 Data Acquisition (1980)

0 2 kilometres

## Remote Sensing Techniques & Waste Management Assessment


M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

# 4. STUDY RESULTS

## 4.1 Archival Photography

The black and white archival photography shows the development of the site from rugged bedrock terrain in 1965 to a major active landfill site in 1978. Data sequences are plotted on Figure E.5.

Surface drainage has been significantly altered by landfill development. Prior to landfilling (1965 photography), a major runoff channel drains most of the site eastward into Falcon Creek. In addition, several small gullies drain the southern area of the site into Falcon Creek. As landfilling progresses, (1972, 1978), the gullies and channels are filled with refuse. By 1978, surface runoff from the fields upslope of the landfill is diverted from the east tributary directly to Falcon Creek. However, runoff from the landfill surface still flows into the tributaries on the east boundary, and a small swale in the landfill surface, coincidentally follows the original drainage path.

Landfilling significantly alters the topography on the site. The steep bedrock scarps and irregular bedrock landscape of 1965, similar to present adjacent bedrock terrain, has been transformed to a rounded, sloping mound by 1978-1980.

By the end of 1980, landfilling along the southwest of the site had slightly enlarged the fill area (compare to Figure E.2).

## 4.2 Late Winter

### 4.2.1 Sensing Conditions

The late winter imagery was flown during the first week in March 1980. Snowfalls were abnormally low during the entire season and at the time of photography snow accumulations were generally confined to protected lows. Therefore, there was no continuous snow cover to provide either the flat background desired on thermography or the contrasting white background desired on the photography to aid in identifying leachate springs. While this may have affected photography data (the red-brown soil cover on-site is similar to leachate staining), the thermography data were not severely influenced since soil and water surfaces were frozen. Weather data prior to 5 March 1980 is listed in Figure E.6.

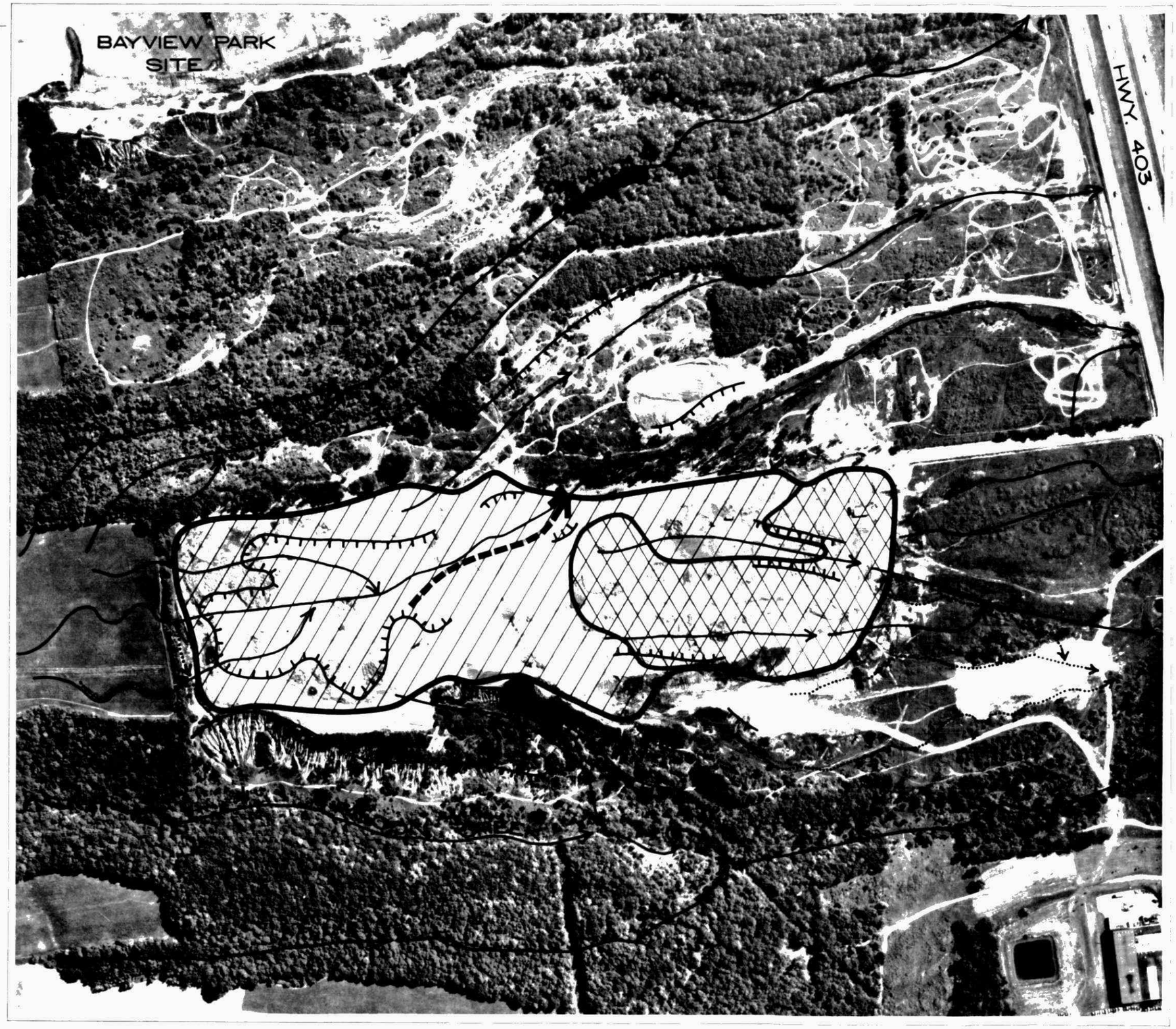
### 4.2.2 Diagnostic Features

a) Colour

Leachate has the same red-brown colouration as the natural surface runoff from the Queenston shale. This coincidence of colour detracts from the usefulness of the colour photography to detect leachate springs.

As an example - reddish-brown staining of a snow covered pool is detected at one location on the landfill. Although leachate seepage has been recorded here, runoff from the red-brown weathered shale and site soil cover causes the same snow staining (see Station 13).

The stations for the following detailed observations are shown on Figure E.7.




Ministry of the Environment
Ontario

# E·5 Archival photography

PRE-LANDFILL CONDITIONS

SURFACE DRAINAGE COURSE

STEEP BEDROCK SCARP

LANDFILL CONDITIONS (1972-1978)

EXTENT OF LANDFILLING 1972

EXTENT OF LANDFILLING 1978

SURFACE DRAINAGE CHANGES

LANDFILL SURFACE RUNOFF

NOTE: INFORMATION USING 1965, 1972 AND 1978 PHOTOGRAPHY

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

FIGURE E.6

WEATHER DATA[1]: BURLINGTON LANDFILL SITE

| DATE | TEMPERATURE (°C) | | | Precipitation[2] |
|---|---|---|---|---|
| | Maximum | Minimum | Mean | |
| Late Winter | | | | |
| February 27 | - 1.0 | - 8.0 | - 4.5 | Tr (S) |
| 28 | - 6.0 | - 14.0 | - 1.0 | |
| 29 | - 12.0 | - 21.0 | -17.5 | |
| March 1 | -12.0 | -19.0 | -15.5 | |
| 2 | - 5.0 | -17.0 | -11.0 | |
| 3 | 6.0 | -16.0 | - 8.0 | |
| 4 | 5.0 | - 5.0 | 0.0 | 5 (R) |
| Spring | | | | |
| April 12 | 12.0 | 4.0 | 7.0 | 2.8 (R) |
| 13 | 9.0 | 1.0 | 5.0 | 1.0 (R) |
| 14 | 7.0 | 1.0 | 4.0 | 7.6 (R) |
| 15 | 4.5 | 3.0 | 4.0 | 8.0 (R) |
| 16 | 4.5 | - 4.0 | 0.0 | |
| 17 | 4.5 | - 5.0 | 2.0 | |
| Summer | | | | |
| July 20 | 29.9 | 23.0 | 26.0 | 1.0 (R) |
| 21 | 32.5 | 21.0 | 27.0 | 3.0 (R) |
| 22 | 33.0 | 20.0 | 26.5 | 7.1 (R) |
| 23 | 28.0 | 16.5 | 23.0 | |
| 24 | 29.0 | 14.5 | 21.5 | |
| 25 | 30.0 | 18.5 | 24.5 | |
| 26 | 25.0 | 19.0 | 22.0 | |
| Autumn | | | | |
| November 17 | 3.0 | - 4.0 | - .5 | .7 (S) |
| 18 | 5.0 | - 2.5 | .5 | |
| 19 | 4.0 | - 5.0 | - .5 | |
| 20 | 8.5 | - 2.0 | 3.0 | |
| 21 | 7.0 | 1.0 | 4.0 | |
| 22 | 9.0 | - 1.0 | 4.0 | |
| 23 | 8.0 | .5 | 4.0 | |
| 24 | 7.0 | 6.0 | 6.5 | 3.8 (R) |
| 25 | 2.5 | 0.0 | 2.0 | |
| 26 | 5.0 | - 4.5 | 0.0 | |
| 27 | 3.0 | - 8.5 | - 2.0 | Tr (R) 3.3 (S) |

1. Source: Burlington weather station
2. (R) rain in mm
   (S) snow in cm
   (Tr) trace in precipitation

Station 7: Stream along the north landfill boundary has melted snow where it flows into Falcon Creek; (the stream is fed by ground and surface water).

Station 8: Red-brown staining of snow on pool at north end of landfill; not conclusive indicator.

Section 13: Reddish-brown staining of snow on pool in bedrock terrain; staining is the result of runoff from redbrown soils.

b) Colour Infrared

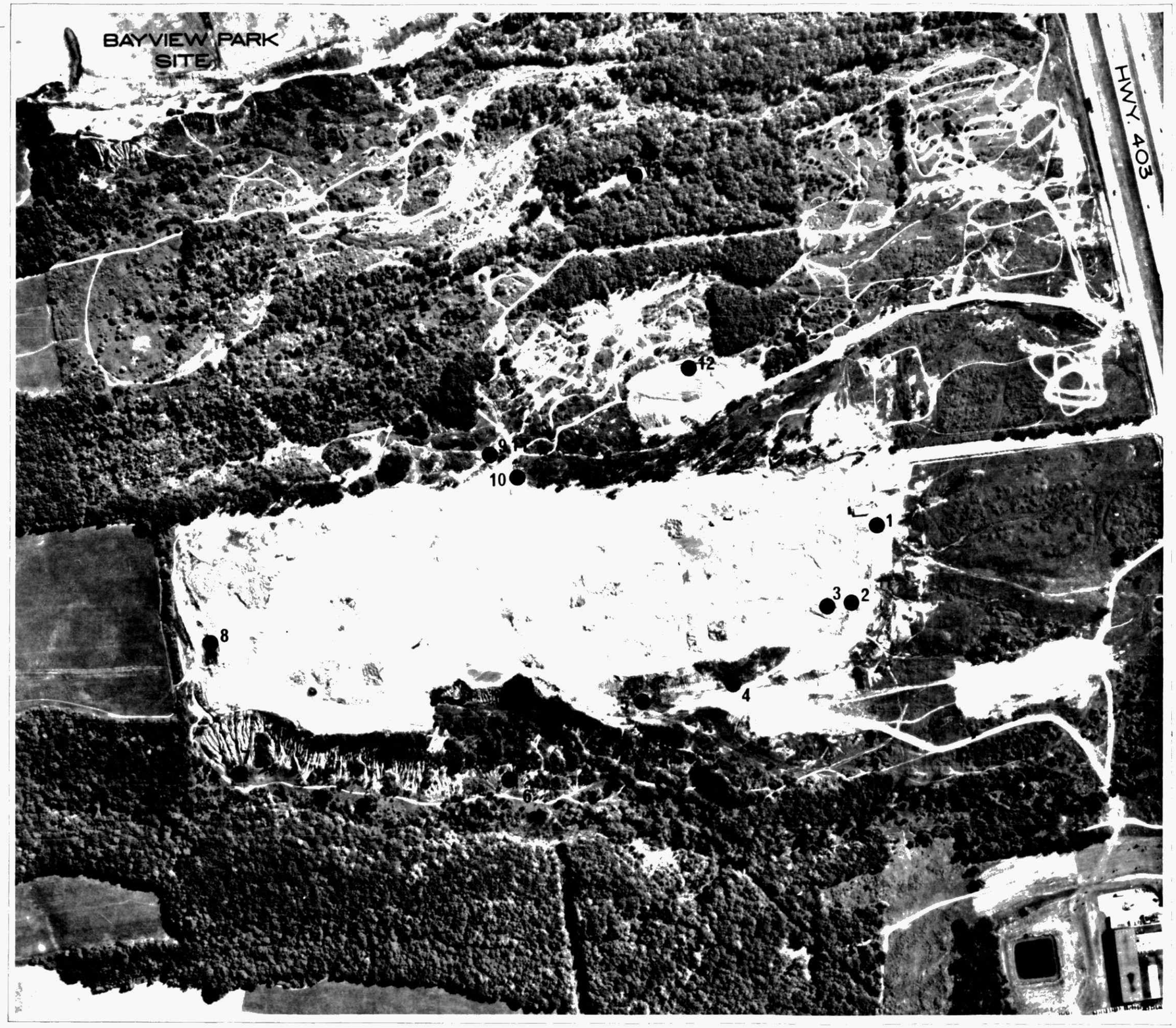
Leachate seepage was not identifiable on the March infrared photography, and thus no results were presented.

c) Thermography

In order to provide good contrast on the thermography for the identification of leachate outbreaks, "level-slicing" (see Volume 1) was performed on the imagery. This has allowed a better interpretation of the results. Thus, the thermal anomalies related to leachate at the Burlington landfill are described as follows:

Stations 1, 9, 12: Leachate seepage points on the thermography appear very warm (white). These warm sources are generally very small in size, with intense brightness, indicating their relatively warm temperatures. It is not possible, however, to distinguish leachate seepage (9) from non-leachate seepage (12).

Stations 6, 10: Ponding is characterized as a somewhat cooler thermal anomaly as compared to seepage points. They can, however, be distinguished by their much broader areal




Ministry of the Environment
Ontario

# E·7 Late winter data
(March 1980)

● 2 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80004-64
COLOUR INFRARED PRINT
– GRS80005-18

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

extent. Once again, it is not possible to distinguish leachate and non-leachate ponding.

Stations 2, 3, 4, 5, 11: These signatures are cooler than those seen in seepage points but have a similar areal extent to those seen in ponding signatures. Station 11 is related to seepage point at Station 9.

## 4.3 Spring Data 1980

### 4.3.1 Sensing Conditions

The 17 April 1980 imagery was acquired under typical spring conditions: leafless deciduous trees, high soil moisture and high surface runoff. Drainage channels are particularly distinct on colour infrared photography and conditions were excellent for photographic interpretation. However, on the thermography increased soil moisture due to recent rains, complicated background information; level slicing, therefore, was used to enhance thermal anomalies. Weather conditions prior to 17 April 1980 are listed in Figure E.6.

### 4.3.2 Diagnostic Features

Observations made on the imagery and in the field are located on Figure E.8.

c) Colour

There are no definite leachate - related diagnostic features on the spring colour photography. Surface runoff is ponded around the site; its red-brown colour is derived from the

surface soils. Leachate seepage is occurring in some pools, but there is no way to distinguish leachate contaminated pools from non-contaminated pools on the photography.

Detailed observations located on Figure E.8 are as follows:

Stations 14, 17, 18, 21, 29, 30, 31: Reddish-brown coloured water ponding around perimeter could be runoff water or runoff and leachate mixed. Compare tone to Station 25.

Station 25: Ponded surface runoff.

Stations 26, 28: Drainage channels originating from east side of landfill are potential leachate seepage areas.

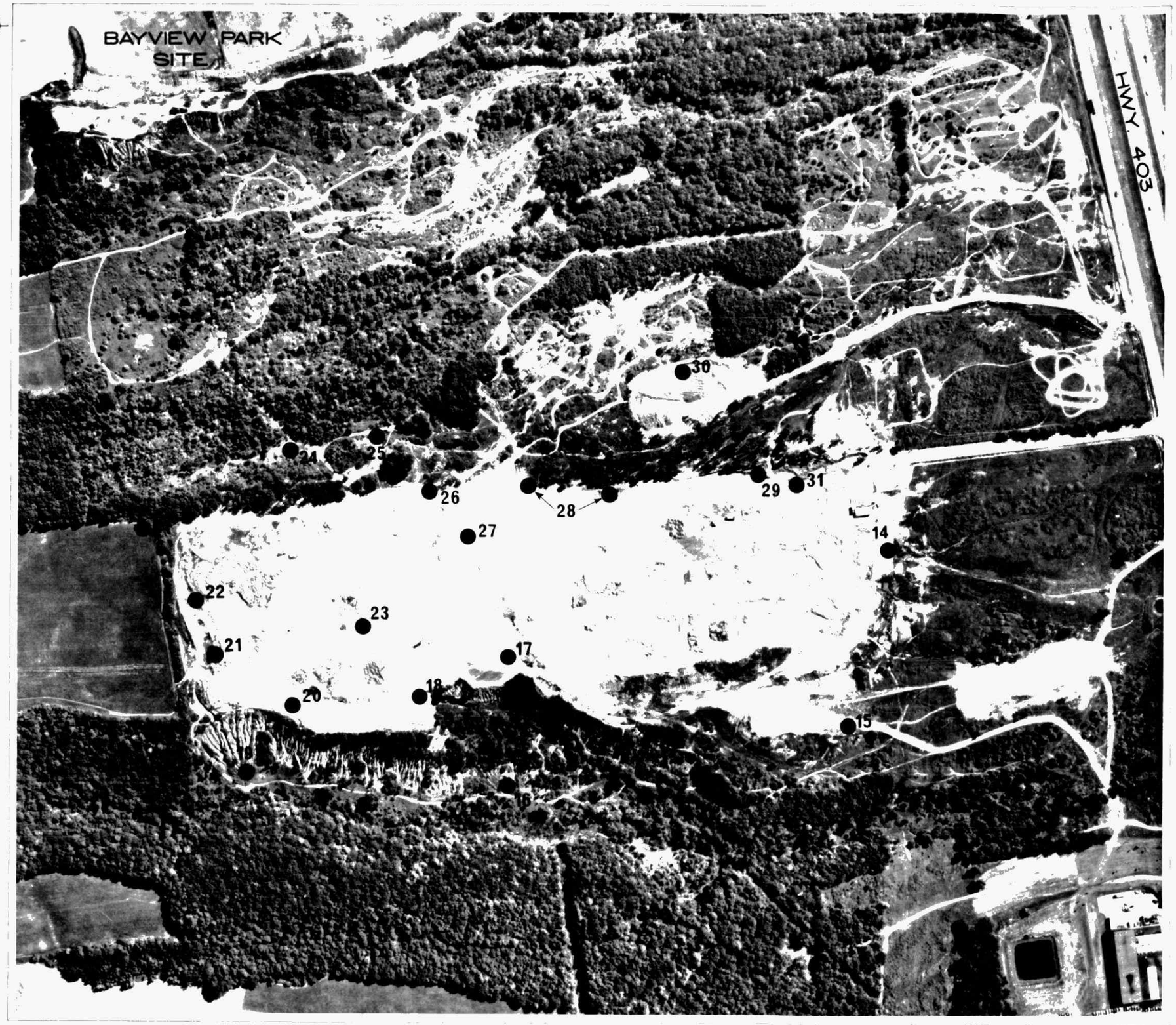
b) Colour Infrared

Only one area of leachate seepage is visible on the colour infrared - soil wetness (dark tones) issuing from the base of a landfill slope.

The sediment laden runoff pools were generally not detected at all on this imagery.

Station 18: Sediment laden runoff pool.

Station 20: Leachate seepage visible as soil wetness (dark soil tone and stream - like pattern).




Ministry of the Environment
Ontario

# E·8 Spring data
## (April 1980)

●20 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS : 80001
COLOUR PRINT – GRS80027-55
COLOUR INFRARED PRINT – GRS80026-18

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

c) Thermography

High soil moisture levels at the Burlington landfill complicate the patterns of thermal anomalies on the imagery. Level-slicing (See Volume 1) was performed to enhance anomalies.

The following are features on the Burlington thermography:

Stations 14, 15, 23: Leachate seepage appears to correlate with thermal anomalies characterized by point-source, very intense brightness on the thermography.

Stations 16, 19, 22, 27: Thermal anomalies around the land fill perimeter show their characteristic ponding signatures much warmer (brighter) than the background and the anomalies cover a larger area than seeps. All stations appear to have one warmer point within the pond. This could suggest that there is leachate entering the pool.

d) Field Observations

Leachate seeps observed on the June field visit are not detected on the earlier imagery (See Figures E.7 and 8). Seeps were generally small and located along the very edge of the landfill. The majority of seepage is occurring in the eastern edge adjacent to runoff gullies. Seeps are perennial and would have been active in April.

Detailed observations are as follows:

Station 14: Leachate seepage at toe drain manhole.

Stations 17, 18, 25: Ponded surface runoff.

Station 20: Small leachate seep from toe of landfill mound.

Station 24: Spring-fed stream crossing Bell right-of-way has 1-2 gpm of flow and conductivity of 800 us (uncontaminated). Location appeared on March thermography as an anomaly.

Station 25: Ponded runoff.

Station 26: Small leachate seep from landfill toe at gully; less than 1 gpm flow, with strong odour and scummy water; conductivity 3,500± us.

Station 27: Dried leachate seep; faint red-brown stain.

Station 28: A series of leachate seeps and springs feed directly into wetland for about 100 m along edge of landfill odour, scummy stained water, and minor bubbling.

Station 29: Previous leachate seepage (dry in June).

Station 30: Seepage from bedrock cut in shale pit flows into wetland; apparently uncontaminated.

Station 31: Previous seepage and surface runoff pond (dry in June).

## 4.4 Summer Data

### 4.4.1 Sensing Conditions

The July infrared photography provided the only conditions for identifying stress in vegetation adjacent to the landfill. At this time, full vegetation cover is healthy

with only grasses and low ground cover showing some moisture stress. Weather data prior to 25 July 1980 are listed in Figure E.6.

In contrast to the optimum conditions for infrared, these same summer conditions are considered least effective for detecting thermal anomalies. Therefore, the unavoidable cancellation of the summer flight was not considered serious.

### 4.4.2 Diagnostic Features

Observations from the summer photography and field visit are located on Figure E.9. Features are often observed on both photography types and confirmed in the field. This was not the case for the spring work previously discussed, where there was little confirmation between sensor results Figure E.8).

a) Colour

Linear staining or wetness extending from the landfill toe indicates leachate seepage zones along the east and south side of the landfill. Features are very small, but associated vegetation kills support this interpretation.

Ponding on site and a clump of dead trees along Falcon Creek are observed on the imagery, but ehri significance is uncertain.

Observations below are located on Figure E.9.

Station 32: Seepage (dark tone) from toe of landfill associated with thin line of bare soil through field vegetation.

Station 33: Clump of dead trees along Falcon Creek.

Station 34: Possible wetland zone at toe of landfill may be due to natural or leachate seepage.

Stations 37, 38: Very small streams (dark staining) from toe of landfill are probable leachate seepage; flow into cattail marsh areas.

Station 40: Stress? (brown tones) within cattail marsh.

Stations 41, 42: Seepage and surface ponding at landfill toe.

b) Colour Infrared

Leachate seepage and associated linear vegetation gaps are identified most clearly on colour infrared imagery because of good total contrasts. The linear dark stain extending from the landfill at Station 32 illustrates this. The imagery shows the sharp contrast between the very thin, vegetation gap (white) and the healthy (red) adjacent vegetation.

Negative vegetation stress is observed: i) in very limited areas at identifed leachate seepage; and ii) along Falcon Creek where a clump of dead trees is mixed with healthy ground cover. The latter feature is not conclusively linked with the landfill. Generally there is no systematic positive or negative stress visible in vegetation around the site.

Ministry of the Environment
Ontario

# E·9 Summer data
(July 1980)

●17 STATION NUMBER AND LOCATION

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (6000)
COLOUR PRINT – 3RSB 0124
COLOUR INFRARED PRINT – 3RSB 0137

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
(Associated with)
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Observations below are located on Figure E.9.

Station 32: Leachate seepage corresponds to dark soil tone and linear vegetation gap for 25 m; note there is no stress visible in adjacent vegetation.

Station 33: Dead trees visible amongst healthy ground cover along Falcon Creek.

Station 34: Minor vegetation stress in valley; may be landfill or seasonal cause.

Station 37: Very narrow linear vegetation gap along valley from toe of landfill.

Station 38: Very narrow linear vegetation gap along valley from toe of landfill.

Station 38: Leachate seepage visible as linear dark soil tone leading into wetland and to linear vegetation gap in wetland (about 25 m long).

Station 40: Linear vegetation gaps and patches of stressed growth (bluish tone) visible in cattail wetland beside landfill.

c) Field Observations

Leachate seepage observed during the August field visit was similar to June observations. Most leachate outbreaks were very small seeps, along the southern and easter toe of the landfill.

The effect of leachate seepage was very limited - vegetation was killed only where leachate actually flowed. Often the

adjacent grass and shrubs made a canopy over the leachate streams. In one area, seepage appaered to be promoting salt tolerant plant growth on the landfill.

Field checking did not confirm any link between the dead trees on Falcon Creek and seepage from the landfill.

Following observations are located on Figure E.9.

Station 32: Active leachate seep at landfill toe has a dark red-black colour, and strong odour; staining extends about 20 m from landfill; no flow along staining or visible stress in adjacent vegetation.

Station 33: Wetland area along Falcon Creek with occasional dead trees; except for dead trees, vegetation is healthy; no clear evidence of leachate contamination.

| | |
|---|---|
| Stream conductivity | - 900-1100 us |
| Ponded water in cattails | - 1500 us |

Station 35: Leachate seeps from toe of fill, draining over crest of valley wall; no flow at this time; odour and surface staining; vegetation is sparse in this area, and seepage may be encouraging salt tolerant vegetation growth, except where leachate actually flows on soil surface.

Station 36: Stream now dry, no evidence of leachate contamination.

Station 37: Leachate seep at toe of landfill; no visible downstream vegetation stress.

Station 38: Leachate seeping from toe of landfill, and occasional seeps occurring for aobut 80 m southward along eastern edge of landfill flow into wetland; vegetation kill only on flow path (less than .3 m wide usually) and for only a few metres from origin.

Station 39: Leachate seep with red-brown surface staining.

Station 40: In some areas of wetland, cattails have died back at tip; no direct link to leachate apparent.

Station 41: Leachate seep.

Station 42: Shallow pool with slight leachate odour and gas bubbles rising through sediment.

## 4.5 Autumn Data 1980

### 4.5.1 Sensing Conditions

The November imagery was obtained under dry soil and leaffree conditions. Temperatures were low, although a light snow fall that covered the ground during the field visit (17 November 1980) had melted by 26 November 1980. Weather data prior to imagery acquisition are listed in Figure E.6.

Autumn is one of the more effective data acquisition periods for thermography. Cold night time temperatures provide a thermally flat background for easier detection of thermal anomalies. Relatively dry soil moisture conditions do not complicate the thermal pattern with mottling. Despite these favourable aspects the imagery was level-sliced (Volume 1) in order to even further enhance the results.

The thermal imagery is, in places, "noisy". This phenomenon is the result of a mechanical problem in taping of the data during acquisition.

Landfill acitivity has ceased in the south part of the site, and this area has received final soil cover and surface grading. The active face is visible on the photography, at the north end of the site.

### 4.5.2 Diagnostic Features

No leachate indicators were interpreted on the colour or colour infrared photography. Observatons from the thermography and field visit are located on Figure E.10.

a) Thermography

Despite the ideal acquisition conditions, anomalies on the theraml imagery are poorly defined. The analog image is very flat, and level slicing did not enhance the detail. Interference further deteriorated the image.

Five warm anomalies are identified, however, as follows:

Stations 44 to 48: Five stations are readily identifiable from the thermography. All of the points have been previously located (Sections 4.3 and 4.2) and have similar Brightness. They differ in their areal extent, with Station 45 appearing to have the greatest thermal extent. This could be the result of image quality, however, rather than actual thermal influence.

Ministry of the Environment
Ontario

# E·10 Autumn data
(Nov. 1980)

●23 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:6000)
COLOUR PRINT
– GRS80164-35
COLOUR INFRARED PRINT
– GRS80163-30

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

b) Field Observations

Field observations confirmed earlier leachate seepage zones. Flow appeared slightly lower than in June or July.

Detailed observations:

Station 43: Former leachate seep covered with final soil cover material.

Station 46: Leachate seepage ponding with surface runoff; conductivity 6000 ± us; near active face.

Station 49: Leachate seep from toe of landfill along gully; very small.

Station 50: Leachate seep marked by red-brown stained ice and soil; less than 5 m long; about .1 m wide.

Station 51: Leachate seepage occurring all along edge of landfill into wetland.

# 5. ANALYSIS

## 5.1 Archival Photography

Potential leachate seepage areas along the east and south sides of Burlington landfill can be identified from the archival photography. Comparison of the 1965 and 1978 data shows that the original surface runoff gullies draining the site to the east and south have been filled with refuse (1978) (Figure E.5). Any leachate discharge from the toe of the landfill will concentrate at these natural lows. In fact, field mapping prior to the toe drain installation identified very acitve seepage from the landfill in these locations. After the toe drain was installed, minor seepage was observed along the east and south edge of the landfill in 1980.

The extent of the landfilled area can also be determined from pre-landfill (1965) and most recent (1978) photography. The smooth topographical mound created by the refuse contrasts sharply with the original, gullied bedrock terrain, and provides a visible boundary of the refuse.

Intervening photography shows the sequence of landfill development but does not add to identification of seepage zones or refuse extent.

## 5.2 Photographic Indicators

There are several types of leachate indicators at Burlington - all observed around the perimeter of the site. Most features, which are very small, imply leachate discharge rather than acutally detecting it. Often these features are inconclusive or unique - occurring only once, on one imagery even at perennial seepage zones.

### a) Vegetation Gaps

Vegetation gaps visible on the summer photography identify some of the leachate seepage entering the wetland east of the site and discharging from the south of the site. These few indicators are the most conclusive on the photography.

The gaps are linear, extending several metres into the ground cover from the landfill toe. Leachate seepage (dark linear stain and wetness) is associated with some gaps, and confirms their relationship to the landfill.

Vegetation adjacent to the gap is healthy, and provides a sharp tonal contrast with the bare soil. This sharp contrast helped identification of some gaps, especially on the colour infrared imagery. However, adjacent healthy vegetation obscured some very small leachate gaps by forming a loos 'canopy' over the seepage stream.

Many larger vegetation gaps around the site relate to landfill site activity or all-terrain vehicle trails through the bedrock terrain.

b) Vegetation Stress

Scattered areas of negatively stressed vegetation appear around the site. There is no visual systematic pattern linking these small stressed zones to the landfill, and field checking does not identify leachate impact. Some stress is probably due to natural environmental factors.

The small clump of dead trees on Falcon Creek may identify earlier landfill impact. However, the stress does not appear to be caused by the current landfill practices. No distinct leachate outbreak is visible in the field, although conductivities indicate some contamination of surface waters.

c) Wetness

Three types of surface wetness indicators are detected on the spring and summer photography.

1) Linear soil wetness and staining (dark tone), related to vegetation gaps are visible on the summer photography. Location, form and association with vegetation identify the dark soil tones as leachate seepage.

2) Seepage from the landfill face (dark soil tone with stream-like form) is detected on the spring colour infrared imagery. This is the only detection of this seepage.

3) Surface ponding occurs around the site during spring, and to a lesser extent in summer. Although some pools are known to be associated with leachate seepage there is no way to distinguish seepage

pools from simple runoff pools on the photography. Point thermal anomalies (e.g. Station 14) at surface ponding provides some indication of leachate seepage.

d) Snow Staining

Red-brown leachate staining is detected on the late winter colour photography at a snow covered pool along the north edge of the site. However, the staining is inconclusive because surface runoff causes the same red-brown staining of snow.

## 5.3 Thermography

By utilizing analog and level sliced thermal imagery, many of the thermal anomalies associated with the Burlington landfill became apparent.

The indicators of leachate seepage at the Burlington landfill site are: signature brightness and shape.

a) Hot-Point Source Indicators

Leachate seepage at the Burlington landfill occurs in many locations around the site. A cluster of outbreak points midway along the east side of the landfill were easily seen as sharp and very distinctly hot thermal anomalies. The same is true of the seepage point which occurs immediately west of the scale house.

A very sharp thermal anomaly was found immediately north of the toe drain in a wooded area. This was identified as a naturally occurring spring.

b) Large-Warm Thermal Signatures

These indicators are very warm (bright) on the imagery and differ from seepage points by their areal extent. Such a phenomenon is seen at the leachate toe drain in the east side of the landfill. The thermography shows a very large L-shaped thermal anomally.

Another zone is near Falcon Creek, along a path directly west and near the mid-point of the landfill. This thermal anomaly is on all three sets of the imagery and may be a leachate seepage point. In April imagery, the signature is even larger than in March and November suggesting some water ponding. There is no field confirmation.

In the April and November imagery large thermally hot signatures can be found at the north perimeter of the landfill. These are ponded areas of leachate at the surface of the landfill. A smouldering garbage fire which is not indicated on the November imagery was also seen near this anomaly.

d) Warm Ground

Warm ground areas were found at the southwest corner of the landfill. Four spots in this area were evident on the March thermography, but field visits did not produce any evidence to determine the cause.

## 5.4 Sensor Evaluation

Detection of leachate seepage is incomplete on all sensors. The most active seepage - along the east side wetland - is identified as a potential area on the archival photography. However, it is not visible on the thermography and was only partly detected on the summer photography. Other seeps on the landfill are detected on only one seasonal imagery, if at all.

The summer infrared film provided the best indicators of leahcate seepage of all of the seasonal photographic imagery taken at this site (Figure E.11). Surface wetness/staining and vegetation gaps interpreted on the east and south sides of the landfill were identified by tonal contrasts. These contrasts were clearer on the colour infrared than on the colour.

Other than these summer observations however, all other photographic indicators for all seasons were indistinct and evidence of leachate seepage was either inconclusive or not detected at all. In fact, no leachate related features were identified on the autumn photography.

Although the thermal imagery was able to detect many of the seepage points found in ground checks, all such seeps were not picked up by the imagery. The March imagery was most effective of all seasons in locating hot-point emissions. This is especially true when using level-slice imagery. The April thermal imagery, while it showed some of the seepage points found in March, also produced many signatures that were not leachate induced.

FIGURE E.11

1980 SENSOR EVALUATION

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Late Winter | | | | |
| 1 | Not observed | N | N | I(spring) |
| 2 | Not observed | N | N | I |
| 3 | Not observed | N | N | I |
| 4 | Not observed | N | N | I |
| 5 | Not observed | N | N | I |
| 6 | Not observed | N | N | I(pond) |
| 7 | Stream | I | N | N |
| 8 | Leachate or runoff stain | I | N | N |
| 9 | Leachate seepage | N | N | Y(seep) |
| 10 | Not observed | N | N | I(pond) |
| 11 | Leachate seepage | N | N | I |
| 12 | Ground water spring | N | N | Y |
| 13 | Runoff staining | I | N | N |
| Spring | | | | |
| 14 | Leachate seep | I | N | I(seep) |
| 15 | Not observed | N | N | I(seep) |
| 16 | Not observed | N | N | I(pond) |
| 17 | Ponded runoff | I | N | N |
| 18 | Ponded runoff | I | I | N |
| 19 | Not observed | N | N | I(pond) |
| 20 | Leachate seep | N | Y | N |
| 21 | Not observed | I | N | N |
| 22 | Not observed | N | N | I(pond) |
| 23 | Soil cover | N | N | I(seep) |
| 24 | Ground water spring | N | N | N |
| 25 | Ponded runoff | I | N | N |
| 26 | Leachate seep | I | N | N |
| 27 | Leachate stain | N | N | I |
| 28 | Leachate seep | I | N | N |
| 29 | Dry leachate seep | N | N | N |
| 30 | Ground water spring | I | N | N |
| 31 | Dry leachate seep | I | N | N |
| Summer | | | | |
| 32 | Leachate seep | Y | Y | |
| 33 | Vegetation | I | I | |
| 34 | Vegetation | I | I | |
| 35 | Leachate seep | N | N | |

FIGURE E.11

1980 SENSOR EVALUATION

(continued)

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Summer - (cont'd) | | | | |
| 36 | Dry stream | Y | Y | |
| 37 | Leachate seep | Y | Y | |
| 38 | Leachate seep | Y | Y | |
| 39 | Leachate seep | N | N | |
| 40 | Vegetation | I | I | |
| 41 | Leachate seep | I | N | |
| 42 | Leachate seep | I | N | |
| 43 | Leachate seep | Y | Y | |
| Autumn | | | | |
| 43 | Soil cover | N | N | N |
| 44 | Soil cover | N | N | I |
| 45 | Not observed | N | N | I |
| 46 | Leachate seep | N | N | I |
| 47 | Not observed | N | N | I |
| 48 | Not observed | N | N | I |
| 49 | Leachate seep | N | N | N |
| 50 | Leachate seep | N | N | N |
| 51 | Leachate seep | N | N | N |

Y - feature identified
N - not identified
I - inconclusive or indistinct

The November imagery had less thermal contrast between the landfill and leachate. Level slicing of the imagery brought out seepage points but these were less crisp than those seen in March.

Site conditions are partly responsible for the poor performance of sensors. Many seeps are just too small to be detected, either visually or as thermal anomalies. The most active seepage is adjacent to the wetland, where vegetation obscures the seepage effects on photography and thermography.

In addition, the Burlington landfill is still an active site where conditions are constantly changing. The toe drain installed in early 1980 reduced active leachate seepage. Application and grading of final soil cover obscure several seeps in November and prevents the clear development of seepage areas on the landfill face. The lack of vegetation and the red-brown soil cover also reduces the contrast between leachate seepage and the background inhibiting opportunities for visual detection.

## 6. IMAGERY USED AT THE BURLINGTON SITE

### 6.1 Archival

Archival photographs used at this site are:

| YEAR | SCALE | PHOTO NUMBER | SOURCE |
|---|---|---|---|
| 1965 | 1:16000 | A19343 # 30-32 | N.A.P.L. |
| 1972 | 1:15840 | 4314-23 #30-31 | M.N.R. |
| 1978 | 1:10000 | 4323-21 # 31-32 | M.N.R. |

### 6.2 1980 Imagery

Figure E.4 shows the area covered by the 1980 imagery. Scales, date and target photographs are given for each imagery set.

### 6.3 Sources

A complete set of imagery is available for viewing at the following offices of the Ontario Ministry of the Environment.

(1980 Imagery):

Solid Waste Unit
Waste Management Branch
Ontario Ministry of the Environment
4375 Chesswood Drive
Downsview, Ontario
M3J 2C2

Central Region
Ontario Ministry of the Environment
Suite 700
150 Ferrand Drive
Don Mill, Ontario
M3C 3C3

Copies of imagery may be obtained from:

1980 Imagery - Contact Ministry of the Environment offices.

Archival:

N.A.P.L.: National Air Photo Library
Energy Mines and Resource
615 Booth Street
Ottawa, Ontario
K1A 0E9
Telephone: (613) 995-4560

M.N.R.: Public Service Centre
Ontario Ministry of Natural Resources
Whitney Block
Queen's Park
Toronto, Ontario
Telephone: (416) 965-1123

# Appendix F
# Upper Ottawa Street site

## Remote Sensing Techniques & Waste Management Assessments

# 1. INTRODUCTION

The Upper Ottawa Street Landfill site is located in the southeast of the City of Hamilton on Redhill Creek (Figure F.1). It is one of the six southern Ontario landfills used in the study "Remote Sensing Techniques and Waste Management Assessment", prepared for the Ontario Ministry of the Environment. The purpose of this study is to evaluate specific remote sensing techniques for application to landfill monitoring and identification.

Colour and colour infrared aerial photography, and thermography was acquired during 1980. This imagery, along with archival photography was interpreted for application in monitoring and identifying existing landfill sites. A summary of the results, comparative evaluation of techniques and final study conclusions are presented in Volume 1 of this report.

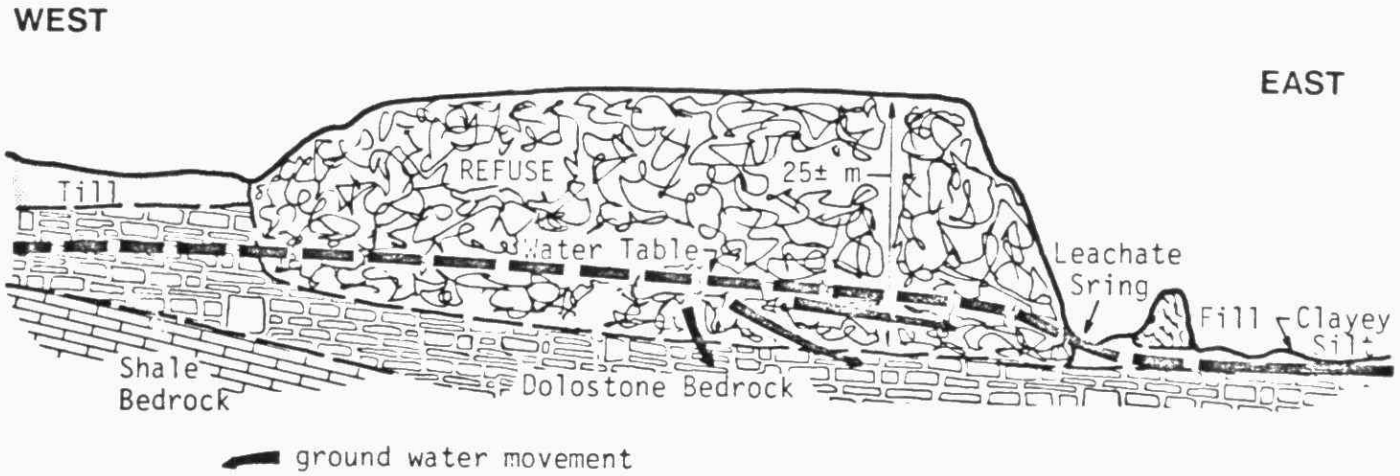
This appendix contains the detailed results for the Upper Ottawa Street site only. The appendix is one of six similar appendices comprising Volume 2. Together they provide all the detailed observations and data accumulated during this study. Each appendix is designed to be used separately with Volume 1, (the general text), if desired.

## 2. BACKGROUND

### 2.1 Physical Setting

Upper Ottawa Street landfill has developed on the former flood plain of Redhill Creek and adjacent lands. The refuse mound rises 15 ± m above the surrounding gently rolling shallow till-limestone plain. Borings through the landfill indicate that refuse was placed directly on the bedrock. These borings were part of a detailed hydrogeological study of the landfill for the Region of Hamilton-Wentworth. Figures F.2, F.3 and the sketch below illustrate the general physical setting.

Schematic Cross Section of Upper Ottawa Street Landfill




Overburden materials are a complex of glaciolacustrine clays and clayey silt till. The slowly permeable soils are generally less than 3 m thick although the till locally reaches 15 m thickness just north of the landfill. (This unit is mapped as moraine on Figure F.2.) The underlying

Ministry of the Environment
Ontario

# F·1 Location map

●

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED

GARTNER LEE ASSOCIATES LIMITED

ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Ministry of the Environment
Ontario

# F·2 Physical setting

LANDFILL AREA

SHALLOW TILL - LACUSTRINE COMPLEX OVER BEDROCK

GLACIAL MORAINE: CLAYEY SILT TILL

BOTTOM LANDS

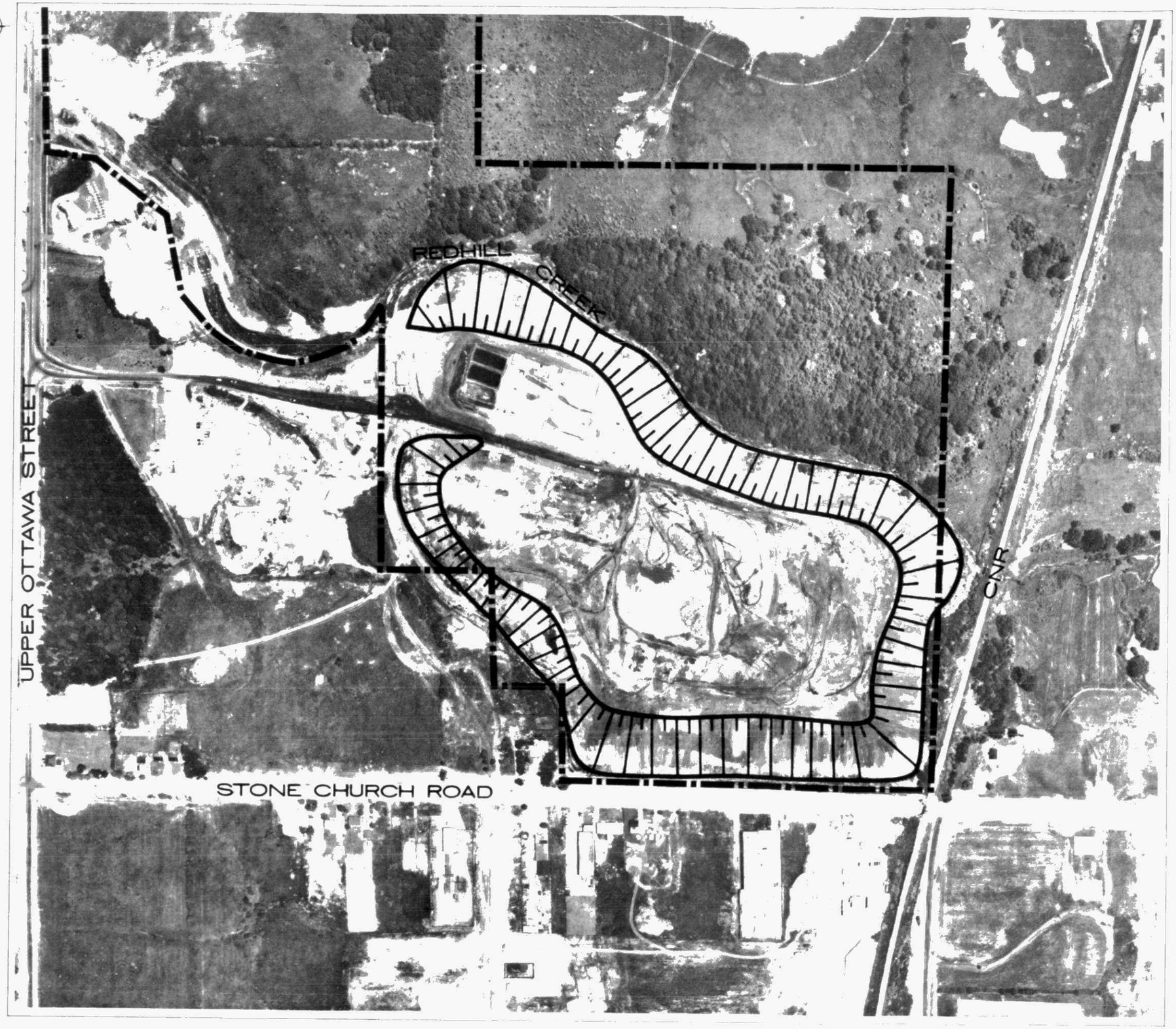
ROCK SCARP

SURFACE DRAINAGE COURSE

CULVERT LOCATION

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES




Ministry of the Environment
Ontario

# F·3 Site plan

PROPERTY BOUNDARY

LANDFILL LANDFORM SIDE SLOPES

NO LEACHATE COLLECTION SYSTEM PRESENTLY IN OPERATION

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

bedrock is Lockport dolomite. Several small bedrock scarps are visible in the area and a small scarp is located along the west side of the landfill.

The site is located in the Redhill Creek watershed. Redhill Creek flows along the north edge of the site in a narrow valley between the landfill and the till moraine. The creek discharges from a culvert just upstream and flows on the bedrock surface west, towards the Niagara Escarpment. A ditch around the west, south and east sides of the landfill collects runoff and discharges it into a sewer catch basin that is located on Stone Church Road.

Hydrogeological investigations carried out for the Regional Municipality of Hamilton-Wentworth, have identified the general hydrogeological setting of the area. There appears to be a slight mounding of the ground water table up into the garbage. Ground water, mixed with leachate, flows outward from this mound. Some of this discharge is manifested as leachate seepage around the lower perimeter of the site. Most of the flow, however, appears to enter the deeper flow system within the bedrock. As such, it cannot be detected by any remote sensing devices.

Seepage emanating from the flanks of the upper portion of the landfill, especially along the west and south sides, appear to be caused by a perched leachate condition within the refuse.

## 2.2 Site History

In operation since the mid 1950's, the site was owned and operated by the City of Hamilton until 1974 and from 1974-1980 by the Regional Municipality of Hamilton-Wentworth. In October 1980, the site was closed.

Prior to 1974 the site comprised an area of 68 hectares serving a population of 300,000 people and received 145,000 tonnes of refuse per year. Landfilling operations were carried out primarily with a bulldozer and front-end loader. However a dragline was used for final grading of the site's steep outer slopes. After 1974 operations were carried out with two landfill compactors and a loader.

Before 1960 wastes landfilled comprised predominantly rubble and stumps, however afterwards increasing quantities of residential were landfilled. In 1964 when the East End (Brantford Street) site closed a significant increase in commercial wastes was noted. In 1968 the West End (Macklin Street) site was closed and in 1970, the Depew incinerator, further increasing waste quantities to the upper Ottawa Street site.

Burning of wastes was reported frequently in the late 1960's and early 1970's with wastes reported as primarily wood with some refuse. Reports of burning continued until 1978.

Discussions with former site staff indicate that up to 1967/1968 water was applied to the refuse to assist with refuse compaction and decomposition. Two runoff ponds were

constructed to supply water for these operatioins. Pumping was often carried out continuously and in addition irrigation of landfill areas was used to quench ashes.

An earth berm was established on the Stone Church Road side of the site to impede the flow of leachate to perimeter ditching. Landfilling was carried out to the maximum height of the berm. Filling began in this area in 1974 when the Region assumed operating responsibility for the site. Leachate was observed flowing through the berm as the landfill reached the height of the berm. Landfilling continued and the berm was maintained at the toe of the landfill slope.

Diversions to the Creek adjacent the site were made to allow for landfilling and excavation work. The toe of the landfill was subsequently constructed up to the creek bank.

In 1979 investigations were being carried out to monitor the pressure and migration of methane gas. It was concluded that gas was not migrating outside the landfilled areas and that concentrations within the site were low or nil.

In 1980 a dyke was constructed to impound the flow of leachate from perimeter ditching to Redhill Creek near the railway tracks. A large leachate impoundment resulted and is pumped periodically to a sanitary sewer on Stone Church Road.

Reports of liquid waste dumping increased in frequency in 1974. In 1976 a liquid waste solidification facility was constructed with the solidified material used to a limited

degree for final covering of the site. Subsequently because of the material's varying consistency the material was disposed of at the site's working face.

Closed in 1980, the site has undergone extensive final covering and grading in the past year. Additional earth fill has been placed and regrading carried out on eroded and settled areas.

## 3.0 METHODOLOGY

The prime objective of the study was to evaluate remote sensing techniques for thier applicability to waste management programs. Six sites were selected for the study and a program for acquisition of remote sensing data for the sites was developed.

Four remote sensors were selected for the study:

i) colour aerial photography
ii) colour infrared aerial photography
iii) aerial thermography
iv) archival photography

Each sensor was expected to be capable of providing specific data on the condition of each site - in particular the discharge of leachate (colour aerial photography and aerial thermography). The sites selected represented a range of differing hydrogeological conditions, with a known history of surface discharge of leachate, and with various stages of site operation and site rehabilitation.

The selected sites were:

Cobourg Landfill Site
Whitby Landfill Site
Oakville Landfill Site
Bayview Park Landfill Site (in Burlington)
Burlington Landfill Site
Upper Ottawa Street Landfill Site -
(in Hamilton)

The program for evaluation of sensors comprised initially the acquisition and review of hydrogeological assessments made

for the site through previous studies. In addition, to assist in providing an understanding of site history and past operations, archival photography was obtained dating back to 1954 and taken at intervals ranging from 5 to 7 years to most recent photography. To further assist in constructing a site development history, a review of Ministry files for the site was made. Observations of site operations and leachate discharge were reported and give insight on the development of leachate mounding and on operational procedures which have conributed to present site conditions.

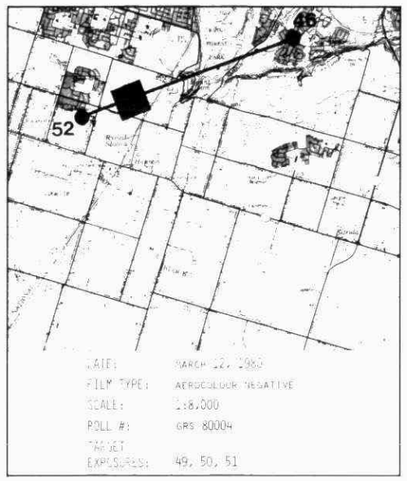
The schedule for remote sensing data acquisition was:

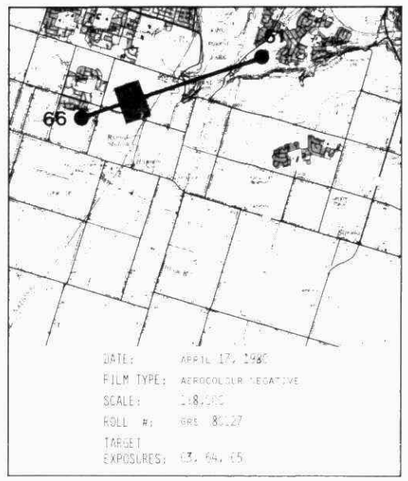
| Sensor | Flight Date | Field Reconnaissance |
|---|---|---|
| colour photography | 12 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 5 May 1980<br>6 August 1980<br>18 November 1980 |
| colour infrared photography | 3 March 1980<br>17 April 1980<br>25 July 1980<br>22 November 1980 | 5 May 1980<br>6 August 1980<br>18 November 1980 |
| thermography | 4 March 1980<br>26 November 1980 | 5 May 1980<br>6 August 1980<br>18 November 1980 |

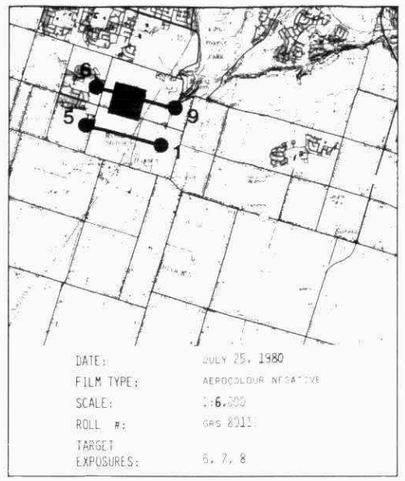
Photography scale was changed from 1:8000 for March and April flights to 1:6000 for July and November flights. Average flying altitude for thermography was 1050 m, giving an approximate scale of 1:14000. Data acquisition details are given on Figure F.4.

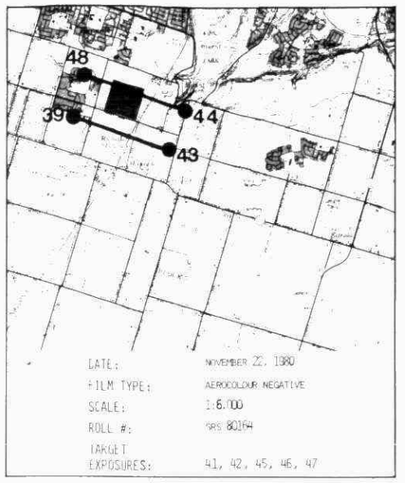
After each flight, photography and imagery were examined and preliminary interpretations made. Detailed field reconnaissance was made to confirm interpretations and to identify any features undetected on the sensor data. Photography and

TRUE COLOUR

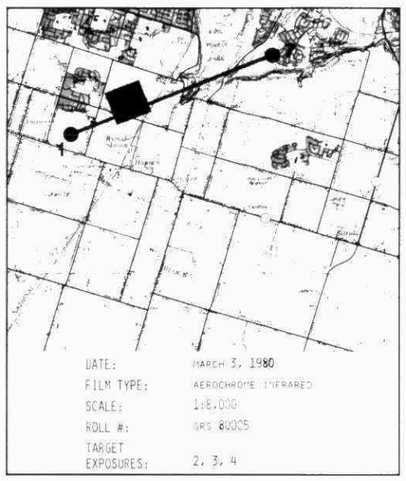


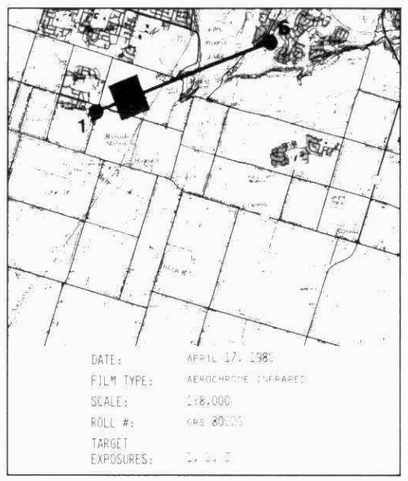



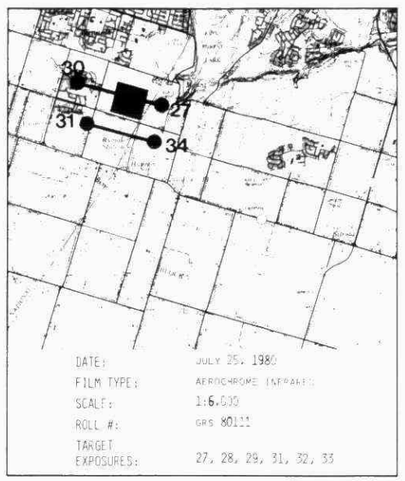



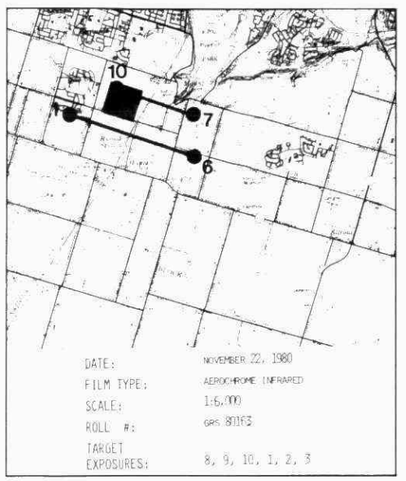




COLOUR INFRARED

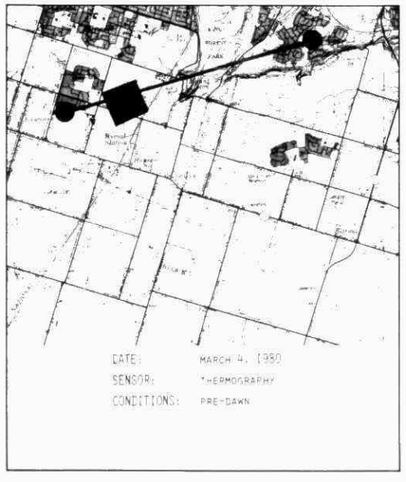


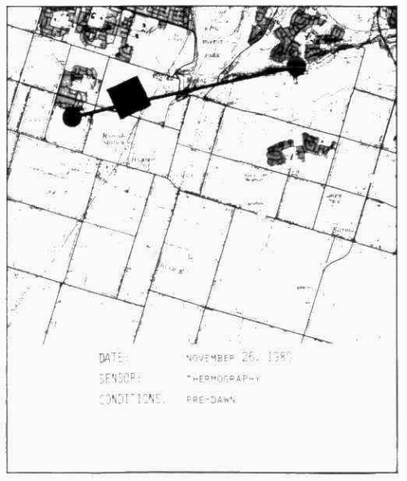




THERMOGRAPHY




LATE WINTER | SPRING | SUMMER | AUTUMN

Ministry of the Environment
Ontario

# Upper Ottawa Street site

## F·4 Data Acquisition (1980)

0 2 kilometres

## Remote Sensing Techniques & Waste Management Assessment


**M. M. DILLON LIMITED**
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

imagery for each flight were annotated and annotations for subsequent flights compared so that assessment of the relative effectiveness of sensors under varying seasonal conditions would be made.

Following completion of all data acquisition, interpretations and field work, comparative assessments of data with respect to season, sensor type, and type and extent of features sensed were made. Site features detectable in the field were noted and compared to those interpreted from photography and imagery. These records and interpretations were used as a basis for determining the effectiveness of each technique.

The relative merits of the various sensors in satisfying the study objective and taking into account relative costs of data acquisition were then assessed.

# 4. STUDY RESULTS

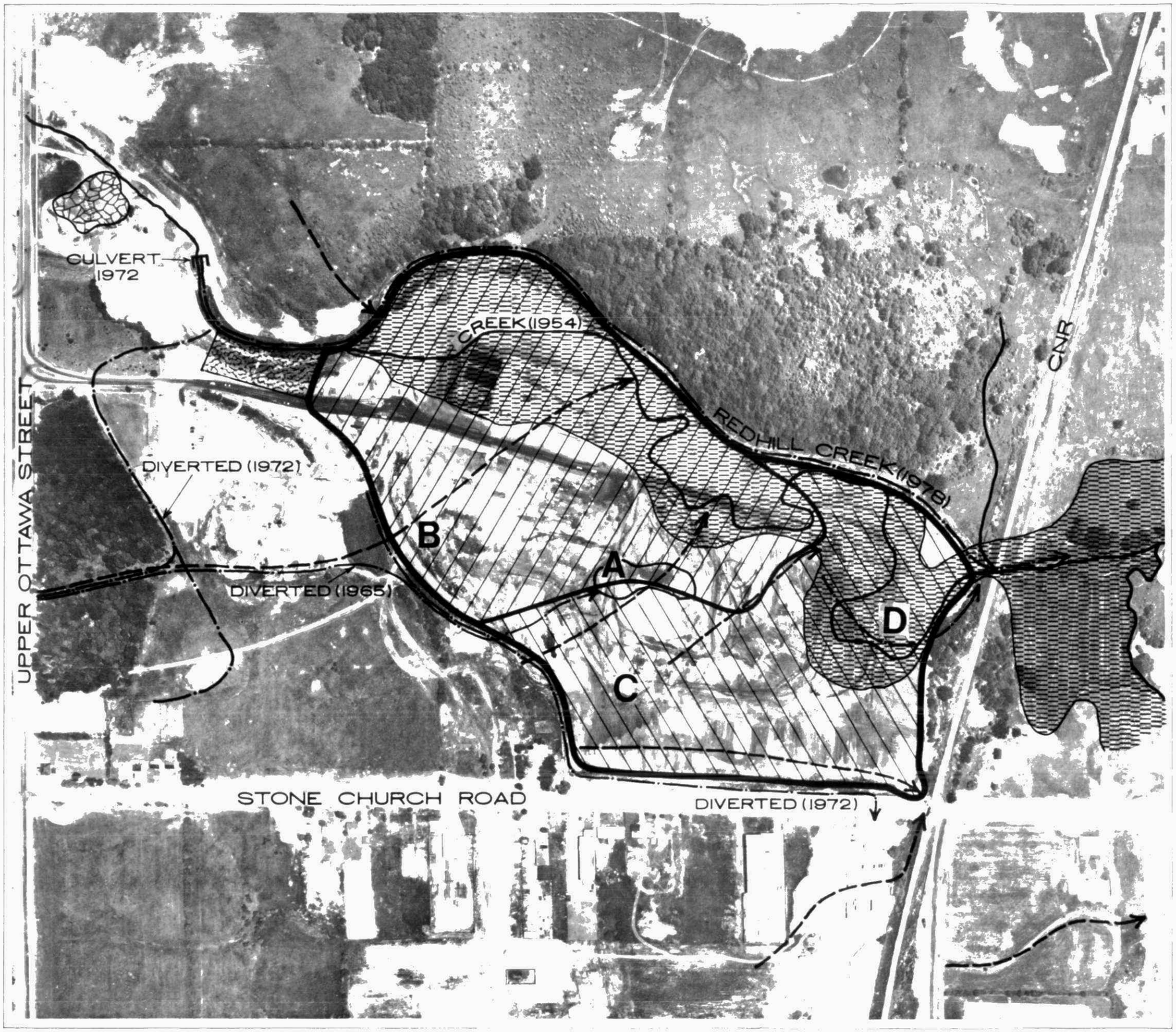
## 4.1 Archival Photography

The existing black and white photography traces the development of the Upper Ottawa Street site from farmland in 1954 to a major landfill and topographic feature in 1978. The sequence of landfilling and drainage diversions are summarized on Figure F.5. Significant details observed in various years are outlined below.

In 1954, Redhill Creek meanders across the eventual site in a wide flood plain. The north stream bank is cut into a steep heavily wooded till slope - about 12 m high. South of the Creek, the land slopes gently towards the flood plain. Several intermittent streams flow across the site.

Upstream of the site, there is a small quarry and an area of disturbed lands. This latter area may identify early landfilling along the Creek, but we have no evidence to support this.

By 1965, the landfill is well established. It has encroached onto a major portion of the flood plain and Redhill Creek is confined between the landfill and the north valley wall. Surface drainage towards the creek has been partially diverted around the south end of the site. However, a large pool has formed at A (Figure F.5) because the landfill blocks flow to the new creek channel. A small deep pool visible at B, confined between refuse and the access road, coincides with the former drainage channel.




Ministry of the Environment
Ontario

# Upper Ottawa Street Site

## F·5 Archival photography

PRE-LANDFILL CONDITIONS (1954)

- SURFACE DRAINAGE
- FLOOD PLAIN, RED HILL CREEK
- QUARRY
- DISTURBED LANDS

LANDFILL CONDITIONS (1965 TO 1978)

- EXTENT OF LANDFILL 1965
- EXTENT OF LANDFILL 1972, 1978
- A TEXT REFERENCE
- SITE DRAINAGE

NOTE BASED ON 1954, 965, 1972 AND 1978 PHOTOGRAPHY

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

By 1972, the landfill has basically extended to its final area. Refuse is mounded in the northwest of the site, while the southeast area is mainly an excavation with fill still below original ground surface.

Redhill Creek is now completely diverted into its narrow valley. Intermittent drainage has been diverted away from the site and a perimeter ditch is being developed along the west and south sides of the landfill. A drainage channel flows along the south end of the fill slope (C to D, Figure F.5) discharging runoff (and leachate) into Redhill Creek at the CNR crossing.

By 1978, the landfill forms a major topographic mound. The perimeter ditch drains into a sewer on Stone Church Road. Surface drainage on the east side of the landfill drains into Redhill Creek at the CNR crossing.

## 4.2 Late Winter Data - 1980

### 4.2.1 Sensing Conditions

Snowfall during the winter of 1979/1980 was low and when the sensing data were acquired, snow accumulation was generally restricted to protected areas. The lack of snow did not seriously affect the thermography results since frozen ground surfaces still provided a good, cool background for detecting thermal anomalies.

The colour infrared photography and the thermography were flown nine days before the colour photogrpahy. During the intervening period, rain and snowfalls modified the sensing conditions. (See Figure F.6 for weather data during this period.)

4.2.2 Diagnostic Features

a) Colour

Dark soil tones, on landfill cover, may identify areas of leachate seepage. However, several darker areas and reddish-brown staining visible on the landfill slopes can be identified as variations in cover material.

The observations below are located Figure F.7.

Station 1: Reddish-brown staining on top of landfill is solidified liquid waste.

Station 2: Redhill Creek is unfrozen; upstream of site, the creek is piped underground.

Stations 7, 11: Darker tone on soil may be leachate seep. Several other areas of dark tone occur between two stations; however, the ditch along west and south of landfill is snow covered and does not have any surface staining or open water.

Station 12: Reddish-brown surface staining is cover material.

Station 13: Pool (snow covered surface) at toe of landfill.

FIGURE F.6

WEATHER DATA[1]: UPPER OTTAWA STREET LANDFILL SITE

| DATE | TEMPERATURE (°C) | | | |
|---|---|---|---|---|
| | Maximum | Minimum | Mean | Precipitation[2] |
| **Late Winter** | | | | |
| March 1 | -11.2 | -21.1 | -16.2 | |
| 2 | - 8.4 | -22.0 | -15.2 | |
| 3 | - 2.6 | -14.5 | - 8.6 | |
| 4 | 2.7 | - 6.2 | - 1.8 | |
| 5 | .9 | - 5.9 | - 2.5 | 4.2 (S) |
| 6 | - 2.8 | -10.2 | -6.5 | Tr (S) |
| 7 | - .4 | - 8.1 | - 4.3 | 2.6 (S) |
| 8 | - 1.3 | - 7.2 | -4.3 | 1.4 (R) 6.2 (S) |
| 9 | - .8 | -11.4 | - 6.1 | |
| 10 | 4.7 | - 4.0 | .4 | 3.0 (R) .2 (S) |
| 11 | - 1.8 | - 9.8 | - 5.8 | .9 (S) |
| 12 | - 5.4 | -13.2 | - 9.3 | |
| **Spring** | | | | |
| April 12 | 10.5 | 3.0 | 6.8 | 5.2 (R) |
| 13 | 6.0 | .4 | 3.2 | |
| 14 | 6.1 | .8 | 3.5 | 8.3 (R) |
| 15 | 5.0 | - .8 | 2.1 | 1.0 (R) Tr (S) |
| 16 | 2.9 | - 5.0 | - 1.1 | Tr (S) |
| 17 | 8.3 | - 4.8 | 1.8 | |
| 18 | 15.4 | 1.0 | 8.2 | |
| **Summer** | | | | |
| July 20 | 29.8 | 20.8 | 25.3 | 2 (R) |
| 21 | 30.9 | 21.8 | 26.4 | |
| 22 | 22.4 | 16.5 | 19.5 | 4.8 (R) |
| 23 | 24.8 | 14.6 | 19.7 | .2 (R) |
| 24 | 26.3 | 12.0 | 19.2 | |
| 25 | 27.3 | 14.5 | 20.9 | |
| **Autumn** | | | | |
| November 17 | .2 | - 6.3 | - 3.1 | 2.0 (S) |
| 18 | 1.6 | - 3.5 | - 1.0 | .4 (S) |
| 19 | 2.4 | - 2.7 | - .2 | |
| 20 | 5.5 | - 2.3 | - 1.6 | |
| 21 | 4.5 | 1.6 | 3.1 | .7 (R) |
| 22 | 7.4 | - 2.6 | 2.4 | |
| 23 | 7.8 | 2.0 | 4.9 | .4 (R) |
| 24 | 5.8 | 1.8 | 3.8 | 4.2 (R) |
| 25 | 1.8 | - 5.5 | - 1.9 | .8 (S) |
| 26 | 2.5 | - 5.9 | - 1.7 | |
| 27 | .9 | -2.7 | - .9 | Tr (R) 2.3 (S) |

1. Source: Hamilton Airport weather station
2. (R) rain in mm
   (S) snow in cm
   (Tr) trace of precipitation

Station 15: Two black bare soil areas exposed on lightly snow covered landfill slope; possible seepage area.

b) Colour Infrared

The colour infrared photography was obtained on 3 March, nine days before the colour photography. Snow cover is lighter and patches of open water (black) appear in the perimeter ditch. No other additional information was obtained.

The observations below are located on Figure F.7.

Stations 6, 7, 11: Dark tones along the lower landfill slope facing Stone Church Road may identify scattered seepage zones in this area. Indistinct observation - potential rather than actual seepage zones. However, Station 6 correlates to a thermal anomaly.

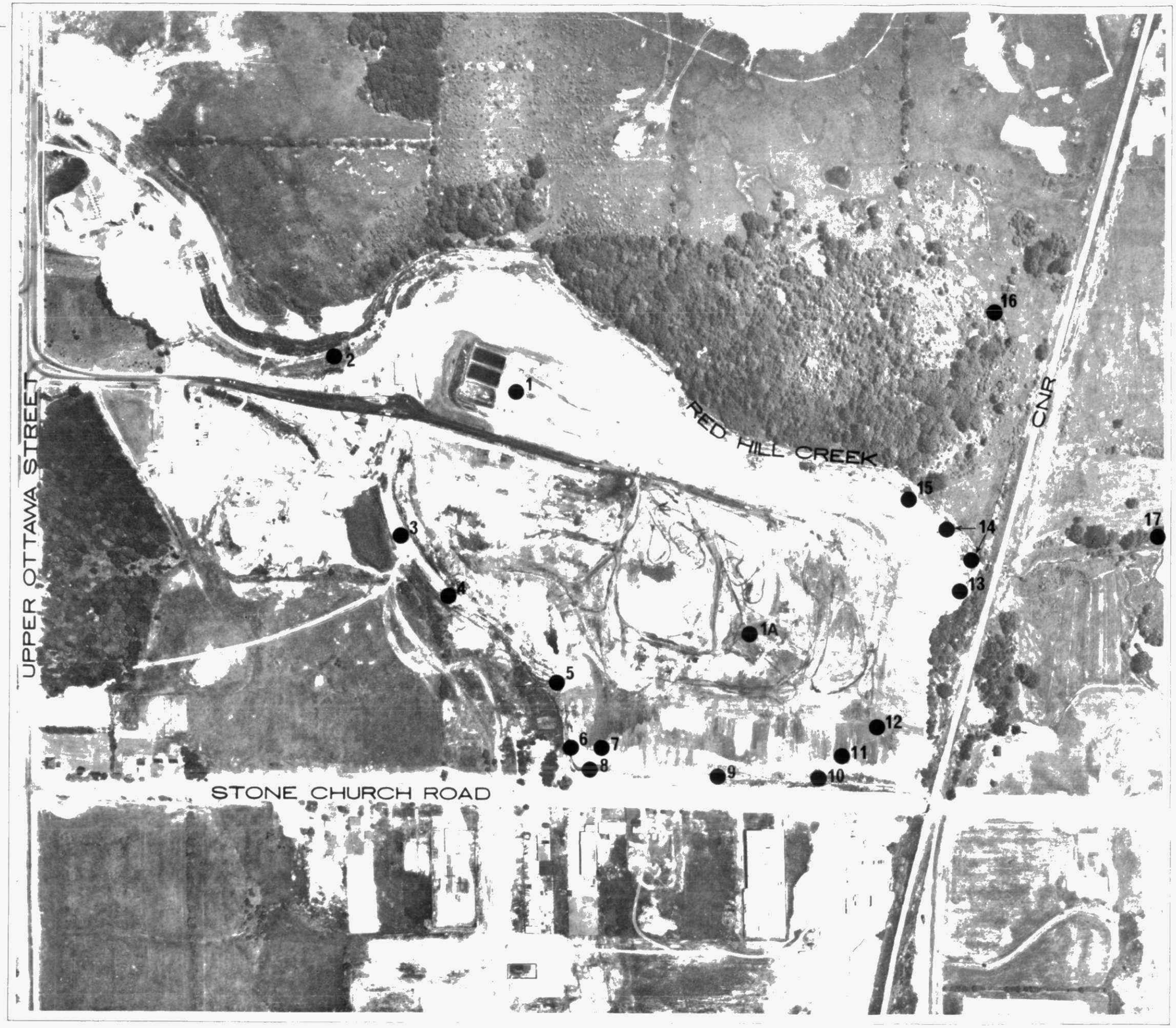
Stations 9, 10: Open water (black) in perimeter ditch suggests leachate seepage is occurring into ditch.

c) Thermography

A series of bright, discrete thermal anomalies are detected on the level-sliced thermal imagery along the west and south side of the landfill. The location and very warm temperature of these anomalies indicate leachate discharge is occurring. Similar, slightly less bright anomalies away from the site locate natural seepage.

Warm anomalies close to the site identify ponded leachate and possible areas of very small scattered leachate seeps.

Redhill Creek appears as a bright anomaly, because of its warm temperature as it discharges from an underground




Ministry of the Environment
Ontario

# Upper Ottawa Street site

## F·7 Late winter data
(March 1980)

●8 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT – GRS80004-50
COLOUR INFRARED PRINT – GRS80005-3

0 100 metres

**Remote Sensing Techniques & Waste Management Assessment**

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

conduit. Downstream of the landfill, concrete channel works and areas of rapids or turbulence along the Creek produce warm anomalies.

Observations described below are located on Figure F.7.

Stations 3, 4, 5, 6, 8, 9, 10 and 14: These stations are characterized by very white intense anomalies, indicating that the origin of seepage has a higher temperature than the surrounding landfill surface. The anomalies have fairly discrete form suggesting point discharge. Their location around the landfill perimeter suggests discharge is leachate.

Stations 5, 8, 10: A warm, pale anomaly giving a halo effect can be seen surrounding these seepage points. This may indicate many small seeps separated by cooler ground, masking of seepage by thin snow cover, or warm ground.

Station 13: A very warm anomaly occurs at the landfill toe, near Redhill Creek. This anomaly, which is differentiated from seepage points by its broader surface area, is probably a pool. Its warm temperature and location adjacent to the landfill suggests leachate is seeping into pool.

Station 16: Bright, discrete thermal anomaly located north of Redhill Creek is similar to above stations. This is natural seepage.

Station 17: Anomaly on Redhill Creek downstream of landfill, occurs at concrete channel works.

## 4.3 Spring Data - 1980

### 4.3.1 Sensing Conditions

The 17 April 1980 imagery was flown with good conditions - leaf-free deciduous trees high water table and high runoff conditions. Unfortunately, navigational problems caused incomplete coverage of the site on the thermography.

Weather data prior to acquisition are listed on Figure F.6.

### 4.3.2 Diagnostic Features

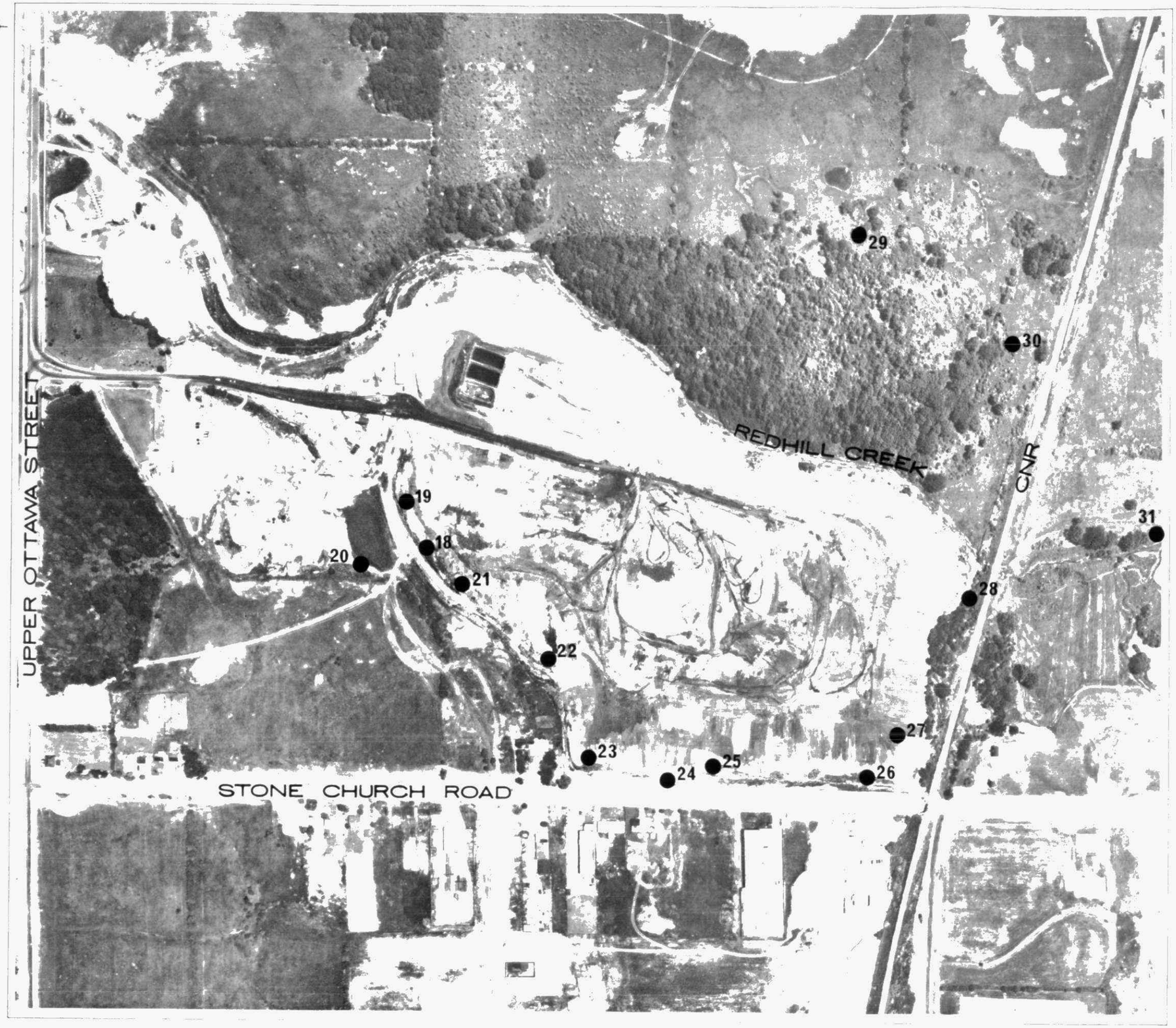
a) Colour

Dark liquid in the perimeter ditch along the west and south sides of the landfill indicate leachate seepage from the landfill toe. A black pool at the landfill toe, confined by a berm from draining into Redhill Creek, also suggests leachate seepage.

Red-brown staining at one location on the south landfill slope indicates a leachate seep from about mid-slope. However, variations in the cover material, showing red-brown staining (solidified liquid wastes) and dark tones, can be confused with potential leachate seepage.

The observations below are located on Figure F.8.

Stations 18-26: Liquid is visible in perimeter ditch on the west and south sides of the landfill. The source of liquid is leachate seeping right from toe of slopes (few springs visible in upper slope).




Ministry of the Environment
Ontario

Upper Ottawa Street site

# F·8 Spring data
(April 1980)

●24 STATION LOCATION AND NUMBER

NOTE: REFERENCE PHOTOGRAPHIC PRINTS (1:8000)
COLOUR PRINT
– GRS80027-64
COLOUR INFRARED PRINT
– GRS80026-2

0 100 metres

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Station 20: Stream draining runoff from works yard.

Station 23: Reddish-brown stain visible on slope; leachate seep.

Station 28: Black pool at toe of landfill slope; confined by berm between pool and creek.

Note: The soil cover tones can be confusing, suggesting seepage or leachate staining.

b) Colour Infrared

The colour infrared film provides no additional data, and observations are generally less distinct. The leachate in the perimeter ditch and in the pool are visible. However, the red-brown staining, which is visible as a faint greenish tone, contrasts poorly with the blue tone of the bare soil.

The observations below are located on Figure F.8.

Station 18: Leachate in ditch along west and south side of landfill is visible.

Station 23: Leachate stain visible at green tone against blue of bare soil; less distinct than on colour photography.

Station 28: Black pool at toe of landfill.

c) Field Observations

Field verification was carried out 5 May 1980. The perimeter of the site, the downstream area along Redhill Creek to Albion Falls and the lands just north of the site were observed in the field.

Numerous leachate seeps and springs were observed at the toe of the landfill. No discharge, however, was observed downstream of the site along Redhill Creek.

The observations below are located on Figure F.8.

Stations 18-26: (Perimeter ditch) Leachate seeping from toe of landfill all along south and southwest faces; flows directly into ditch; along the south face there is also intermittent seepage about 3 to 5 m above ditch level (Stations 23-26).

Station 19: Seepage (and runoff springs) at base of slope, entering leachate collection ditch (Figure F.9).

Station 21: Change in cover material colour. Active leachate seeps about 1 to 2 m from base of slope.

Station 22: Active seepage about halfway up slope and about quarter way up slope.

Station 23: Classic red-brown leachate staining and seeps for about 20 m from west corner of fill along south face; about 5 to 9 m up slope from ditch; continues along to new soil cover area.

Station 25: Small seepage spring; only visible seepage in this stretch of slope.

(A) Leachate seeping from toe into perimeter ditch

(B) Leachate staining soil surface: some vegetation kill

Figure F.9 Leachate seepage, Upper Ottawa Street Landfill

Station 26: From 26 to east corner of south face, active seeps and considerable iron staining on grass and soil; seeps and springs from 5 m height along slope; ditch at base of fill diverted into catch basin.

Station 27: East face fill; red stains at southest corner observed on colour photography are solidified liquid waste.

Station 28: Leachate pool between railway embankment and northeast face, dammed at north end; pool pumped out approximately every two days, leachate diverted to catch basin on Stone Church Road; very active seepage along edge of pond; seepage under dam at north end of pond.

Station 29: Area of shallow ponds, north of Redhill Creek valley; conductivity 300 ± us.

Station 30: Ground water spring northeast of landfill, west of railway; conductivity 300 ± us temperature 10°C; stream channel on top of slope, near spring conductivity 300 ± us.

Station 31: Concrete channelization work along Redhill Creek, downstream from landfill; conductivity of Creek 1100 ± us.

Note: Field work during Spring of 1981 identified leachate discharge along Redhill Creek Valley, near Albion Falls; back-checking the 1980 imagery identified no evidence of this discharge.

## 4.4 Summer Data - 1980

### 4.4.1 Sensing Conditions

The 25 July 1980 photography provided the only opportunity to examine possible vegetation stress around the site perimeter and downstream, on the colour infrared film. Some natural stress due to summer drought is visible in ground cover in open fields. Trees and vegetation in wet areas are vigorous. Clouds obscure part of the site on some colour infrared prints. Weather conditions prior to acquisition are listed in Table F.6.

### 4.4.2 Diagnostic Features

a) Colour

The leachate pool, the dark liquid in the perimeter ditch, the red-brown staining on soil cover and a small seep visible along Redhill Creek identify leachate seepage around the landfill toe. However, the red-brown staining is less distinct than on the spring photography.

Most of the vegetation gaps that occur frequently in the ground cover that grows on the lower landfill slopes are natural and not caused by leachate. However, it is not possible to distinguish the natural from the leachate caused gaps on the colour photographs.

The observations below are located on Figure F.10.

Station 32: Dark liquid in perimeter ditch suggests leachate seepage from toe.

Station 35: Faint reddish staining on slope with vegetation gap; leachate seep.

Stations 40, 42, 43: Vegetation gaps and faint seepage (dark soil) are combination of natural and leachate-induced features. Difficult to distinguish.

Station 44: Leachate pool.

Station 46: Leachate seepage from toe of landfill.

b) Colour Infrared

A definite area of soil wetness (dark tone) starting about mid-slope on the landfill face is visible on the colour infrared film. This is the only photographic identification of this seep. Generally, however, leachate seepage from the landfill toe is again implied from the leachate visible in the perimeter ditch and the leachate pool.

Vegetation effects are inconclusive as indicators of leachate activity. Natural and leachate-caused vegetation gaps near the landfill toe could not be distinguished on the photographs. A random mixture of healthy and stressed vegetation is visible along the perimeter ditch - much of the negative stress may be simply due to summer drought. Healthy vegetation is visible growing in areas of known active seepage.

The observations below are located on Figure F.10.

Station 32: Dark tone all along perimeter ditch indicates leachate toe spring.

Station 33: Dark tone on slope suggests leachate seepage; not seen on colour.

Station 35: Vegetation gap with no staining visible.

Stations 38, 39-43: Vegetation on landfill slope and ditch shows mixture of stressed and non-stressed vegetation. Much of this may be due to summer drought. Natural and leachate-caused gaps not distinguishable.

Station 44: Leachate pool.

Station 45: Stress visible in a small patch of vegetation on landfill toe.

Station 46: Seepage at toe.

Stations 47, 48: Vegetation stress in the grasses (47) along Redhill Creek, and in the trees (48) north of the Creek may be related to the landfill.

c) Field Observations

The 6 August 1980 field visit confirmed the active leachate discharge from the landfill toe. Along the south landfill face (parallel with Stone Church Road) leachate was discharging at the toe and in a rough line about 5 m above the toe, many of these upper seeps had killed vegetation but only in the direct path of leachate flow. Colour of leachate staining varied from black to reddish-brown.

Ministry of the Environment
Ontario

# F·10 Summer data
(July 1980)

●41 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:6000)
COLOUR PRINT
– GRS80IIC-7
COLOUR INFRARED PRINT
– GRS80III-29,33

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

Apparently healthy vegetation is growing immediately above the leachate discharge zones at the landfill toe (Figure F.9) or adjacent to the leachate outbreaks on the slope. Most species are hardy and salt tolerant.

The observations below are located on Figure F.10.

Station 32: Perimeter ditch collects leachate from numerous seeps along toe, healthy vegetation growing all along toe, above seeps. (Salt-tolerant vegetation.) This occurs all along perimeter ditch, to Station 43.

Station 34: Very active leachate spring at toe (1-2 gpm).

Stations 34-35: Seepage occurring about 3 m above toe of slope; healthy vegetation along ditch.

Station 35: Leachate seeps, red-brown staining and vegetation kills extend about 30 m along slope. Largest single kill about 3 m wide.

Station 36: Leachate seep with dark red staining and vegetation kill about .3 m wide.

Stations 37, 38: Leachate seepage with dark red staining and vegetation kill.

Station 43: Leachate seepage and vegetation kill.

Stations 35-43: Stone Church Road - leachage seeps occur about 5 m above ditch; seeps and springs at toe of landfill slope are not located individually and are not visible directly on imagery.

## 4.5 Autumn Data - 1980

### 4.5.1 Sensing Conditions

The November 1980 imagery was obtained under late autumn conditions. Deciduous trees were leaf-free and an earlier snowfall that covered the site during the 18 November field visit had melted. Weather conditions prior to 26 November 1980 are listed in Figure F.6. Because of the season, most of the north slope of the landfill, along Redhill Creek, is obscured on the photographs by shadow.

Sensing conditions are excellent for thermography at this season. The cold nighttime temperature and low soil moisture provide a thermally flat background for easier detection of leachate springs. Unfortunately, some "noise" is visible on the imagery as a result of a mechanical problem during data acquisition. This "noise" could not be removed.

The Upper Ottawa Street landfill closed on 8 October 1980 and at the time of autumn photography final soil cover is being applied over the entire site. Although most of the site surface was being regraded, the extremely steep slope angles at the landfill toe (see Section 2.2) prevented cover being placed over most toe springs.

### 4.5.2 Diagnostic Features

a) Colour

Leachate seepage could be implied from red-brown liquid flowing from the perimeter ditch into the sanitary sewer on Stone Church Road and by very faint red-brown soil staining

at another station. Vegetation gaps are still visible along the lower landfill slope facing Stone Church Road, but there is no feature to identify natural versus leachate related gaps.

The observations below are located on Figure F.11.

Stations 49-53A: Leachate in perimeter ditch, intermittent.

Station 51: Vegetation gap has very faint reddish-brown staining.

Station 52: Vegetation gaps visible all along the lower slope facing Stone Church Road; origin of gaps, whether erosion or leachate, cannot be distinguished on photograph.

Station 53A: Leachate (red-brown liquid) flowing into catch basin from perimeter ditch.

b) Colour Infrared

The leachate in the perimeter ditch has intermittent dark tones and dark coloured flow into the Stone Church Road sanitary sewer. These features are less distinct than on the colour photos. Vegetation gaps are clearer on this film but, again, natural and leachate related gaps cannot be distinguished.

The observations below are located on Figure F.11.

Stations 51, 52, 54: Vegetation gaps are distinct but one cannot distinguish natural and leachate-caused gaps on photograph.

Station 53A: Leachate flowing from perimeter ditch into catch basin (53A) is just identifiable.

c) Thermography

Numerous descrete, bright (hot) anomalies are identified on the thermography around the landfill perimeter. The location and intensity of these features suggests they are leachate discharge areas. Less intense anomalies at the landfill toe and on Redhill Creek may also identify leachate discharge. These features were identified after the data were levelsliced to enhance anomalies.

The observations below are located on Figure F.11.

Stations 49, 50, 53, 57, and 59: Apparent leachate seepage areas are characterized by bright (hot) discrete anomalies around the site perimeter. Most of these seepage points are located along the toe of the landfill; however, Stations 50, 55, and 57 appear to be located about midway up the landfill slope.

Station 56: Warm anomaly locates the leachate pool.

Stations 53, 54: Warm thermal anomalies, less intense and less discrete than above features, are located at the landfill toe. These may identify smaller leachate seeps.

Station 61: A warm thermal anomaly is located along Redhill Creek; possible seepage into Creek.

Ministry of the Environment
Ontario

# F·11 Autumn data

●49 STATION NUMBER AND LOCATION

NOTE REFERENCE PHOTOGRAPHIC PRINTS (1:6000)
COLOUR PRINT
– GRS80164-46
COLOUR INFRARED PRINT
– GRS80163-9

## Remote Sensing Techniques & Waste Management Assessment

M. M. DILLON LIMITED
in association with
GARTNER LEE ASSOCIATES LIMITED
and
ONTARIO CENTRE FOR REMOTE SENSING
MINISTRY OF NATURAL RESOURCES

d) Field Observations

The 18 November 1980 field visit confirmed active leachate seepage along the west and south toe of the landfill and at the leachate pool. Small scattered seeps were observed at the landfill toe on Redhill Creek.

The observations below are located on Figure F.11.

Stations 49-53: Leachate is seeping at numerous locations from the landfill toe into the perimeter ditch along the Stone Church Road side, several leachate seeps are discharging on the landfill slope about 5 m above the ditch.

Stations 52, 54: Vegetation gaps along the Stone Church Road perimeter of the landfill.

Station 53A: Leachate is flowing into the sanitary sewer catch basin, on Stone Church Road.

Station 56: Leachate pool.

Stations 58, 60: Leachate seep from landfill toe into Redhill Creek.

Station 61: Several small leachate seeps at landfill toe enter Redhill Creek.

## 5. ANALYSIS

### 5.1 Archival Photography

The landfill area and general location of leachate discharge can be determined from interpretation of 1954 and 1978 photography. The obviously man-made "hill" visible on the 1978 photography, and the diverted surface drainage, identify the extent of the landfill area. Development of such a large mound in the original shallow till environment may create a leachate mound within the refuse. And while leachate will move downward into the rock, at least some will discharge at the landfill toe, predominantly at Redhill Creek - as indicated in the detailed hydrogeological study conducted for the Regional Municipality of Hamilton-Wentworth.

Identifying the sequence of drainage changes on photography between 1954 and 1978 provides additional information for understanding the observed pattern of leachate seepage. The main feature is a temporary channel that drained the landfill excavation (D, Figure F.5) into Redhill Creek. This channel, detected on 1972 imagery, correlates with the location of vigorous discharge into the leachate pool, near the CNR crossing at Redhill Creek.

### 5.2 Photographic Indicators

Colour and colour infrared photography identifies leachate seepage at Upper Ottawa Street primarily by the use of inductive interpretation - i.e., dark liquid flowing in perimeter ditch and pool. Direct detection is not common and

is usually inconclusive. The main indicators are wetness (perimeter ditch), staining, snow gaps and vegetation effects.

a) Wetness

Dark liquid (leachate) detected in the perimeter ditch is the only indicator of the numerous active leachate springs discharging from the west and south landfill toe. A black pool of leachate identifies a very active discharge area on the east side of the landfill near Redhill Creek. However, runoff from the adjacent works yard produces similarly dark coloured liquid - so the feature is not a completely conclusive leachate indicator.

Soil wetness, visible as a dark tone on the landfill slope, identifies one leachate seep on the summer colour infrared photos and may locate some small seeps on the spring colour photos. However, the latter wet areas are very inconclusive and often the apparent seepage is really a variation in the soil tone of final cover materials.

b) Staining

One leachate seep is identified by light red-brown staining on the landfill slope, associated with a vegetation gap. This staining is just visible on the colour infrared photos because of the lack of contrast between the staining and the background soil. In addition, the red-brown colour is not unique - the solidified liquid wastes which were disposed on-site in different periods have the same red-brown tone. And before application of final soil cover over the site, this material could be confused with leachate staining when it was exposed at the landfill surface.

It is also interesting to note that several very dark leachate seeps discharged on the south landfill face during the summer. None of this staining is detected, despite sharp contrast with the soil background.

c) Snow Gaps

Two gaps in the snow collected along the perimeter ditch identified potential leachate seepage from the landfill toe. These gaps were detected on the colour infrared March photographs, but not on the colour prints which were flown nine days later.

d) Vegetation

Gaps in the vegetation at the landfill toe were detected on colour and colour infrared photos from April to November. Although some gaps were caused by leachate discharge, many are natural - the site was active until October and only natural pioneering revegetation has occurred. Unfortunately, both types of gaps appear identical on the photography. One exception is mentioned above, where red-brown staining is observed at a vegetation gap.

Stress is an inconclusive indicator on the summer photography. Healthy salt-tolerant species were observed growing immediately above vigorous toe springs in the field (Figure F.9) and on the aerial photographs. Much of the negative stress around the site is probably due to summer drought. Slight vegetation stress along Redhill Creek downstream of the site may be seasonal or landfill related.

## 5.3 Thermal Indicators

Leachate seepage at the Upper Ottawa Street landfill site can be detected by thermographic interpretation. The indicators of these leachate seepages on the thermography are: hot (bright) point source thermal anomalies, hot expansive thermal anomalies and relatively warm thermal signatures.

During the early spring and fall, the surface of the landfill is much cooler than the leachate springs which give rise to these relatively hot thermal signatures. The imagery was level-sliced to enhance the interpretation.

a) Hot Point-Source Signatures

Major seepage points at the Upper Ottawa Street site occurred at the toe of the landfill along the southwest slope. Leachate exits from the landfill at points along the toe and flows along the ditch. The March thermography detects the hot emissions from this source and indicates the direction of flow by detecting the gradual cooling of the thermal signature to the south. There is no evidence of this feature in November.

Two seepage points are also picked out along the south toe of the landfill. Their relatively bright signatures indicate very hot thermal anomalies. With careful scrutiny, very small hot points can be seen, in a line, along the south toe in the November thermography. The two large thermal anomalies correlated well with substantial leachate seepages. The smaller points were not identified as leachate during field checking.

Along Redhill Creek, point-source signatures on March and November thermography correlate with a seepage point at the toe of the northwest corner of the landfill. A zone of multiple point-source thermal anomalies related to the cluster of suspended leachate outbreaks, were found along the east wall. These were only visible on the November imagery.

Very small but distinct thermal anomalies can be found along the north face near the creek. Again, these were substantiated as leachate induced anomalies.

Several "hot-spots" were found downstream fo the landfill. These appear to be indicators of open and turbulent water and concrete creek liners rather than leachate contamination.

b) Hot-Expansive Signatures

A single thermal signature of this type can be found along the east wall of the landfill. In November, the anomaly is much broader in area than in March. This open pool is the leachate pond which in November is open while in March is partially frozen. While this is not a clear indicator of leachate contamination, association of ponding of this type, in very close contact with the landfill, would certainly require closer investigation.

c) Warm Thermal Anomalies

A very wide and elongated warm area can be found on the March thermography along the foot of the south slope. While this area is associated with heavy leachate staining, the thermal signature is much the same as that in the woodlot immediately north of the landfill. While these zones of warm ground can be associated with landfill phenomena they cannot be used as positive leachate indicators.

## 5.4 Sensor Evaluation

Interpretation of archival photography is a very effective tool in locating the extent of landfilling and in predicting possible leachate discharge areas at the Upper Ottawa Street

site. Photography during operations of the landfill is able to help in understanding the location of some vigorous leachate discharges.

With regard to 1980 photography, colour and colour infrared imagery are fairly equal in detecting leachate seepage (Figure F.12). Results are poorest in March, when snow obscured the main photographic indicator - the perimeter ditch. For the remainder of the year, the leachate ponding around the site and most of the indicators are slightly more distinct on the colour than on the colour infrared photography. However, the difference is not significant.

Generally, the indicator features, other than the perimeter ditch, are visible in only one season or are too inconclusive to link to leachate seepage. Unfortunately, the lack of site vegetation minimized the usefulness of colour infrared film for identifying vegetation stress.

In addition, the photography failed to detect several leachate toe springs along Redhill Creek and several leachate seeps on the south landfill slope. This may be due to the small size of seeps or a lack of contrasts with the background soil. But several seeps on the landfill slope were characterized by very dark leachate staining running across the soil to the perimeter ditch.

Thermography identified many leachate discharge areas as discrete anomalies around the site. The best data were obtained in March (Figure F.12). However, both the March and November thermography failed to detect many small seeps and, notably several larger leachate seeps exposed on the landfill face. Furthermore, the thermal anomalies are not unique and must be field checked to confirm apparent ground conditions.

FIGURE F.12

1980 SENSOR EVALUATION

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Late Winter | | | | |
| 1 | Solidified liquid waste | Y | Y | N |
| 2 | Redhill Creek | Y | Y | Y |
| 3 | Leachate seeps | N | N | Y |
| 4 | Leachate seeps | N | N | Y |
| 5 | Leachate seeps | N | N | Y |
| 6 | Leachate seeps | N | I | Y |
| 7 | Leachate seeps | I | I | N |
| 8 | Leachate seeps | N | N | Y |
| 9 | Leachate seeps | N | Y | Y |
| 10 | Leachate seeps | N | Y | Y |
| 11 | Leachate seeps | I | I | Y |
| 12 | Red-brown final cover | I | N | N |
| 13 | Leachate pool | I | N | Y |
| 14 | Leachate seep | N | N | Y |
| 15 | Soil cover | I | N | N |
| 16 | Ground water spring | N | N | Y |
| 17 | Concrete channel | Y | Y | Y |
| Spring | | | | |
| 18 | Leachate seep | Y* | Y* | |
| 19 | Leachate seep | Y* | Y* | |
| 20 | Works yard drainage | Y | Y | |
| 21 | Leachate seep | Y* | Y* | |
| 22 | Leachate seepage | Y* | Y* | |
| 23 | Soil staining | Y | I | |
| 24 | Leachate seepage | Y* | Y* | |
| 25 | Leachate seepage | Y* | Y* | |
| 26 | Leachate seepage | Y* | Y* | |
| 27 | Leachate seepage | Y* | Y* | |
| 28 | Leachate pool | Y | Y | |
| 29 | Run-off pond | Y | Y | |
| 30 | Ground water spring | N | N | |
| 31 | Concrete channel liner | Y | Y | |
| Summer | | | | |
| 32 | Leachate seep | Y* | Y* | |
| 33 | Leachate seep | N | Y | |
| 34 | Leachate spring | N | N | |
| 35 | Leachate stain | Y | I | |
| 36 | Leachate seep and stain | N | N | |
| 37 | Leachate seep | N | N | |
| 38 | Vegetation | N | I | |

FIGURE F.12
1980 SENSOR EVALUATION
(continued)

| STATION | FIELD OBSERVATION | COLOUR INDICATOR | COLOUR INFRARED INDICATOR | THERMO-GRAPHY INDICATOR |
|---|---|---|---|---|
| Summer - (cont'd) | | | | |
| 39 | Vegetation | I | I | |
| 40 | Vegetation | I | I | |
| 41 | Vegetation | I | I | |
| 42 | Vegetation | I | I | |
| 43 | Leachate seep | I | I | |
| 44 | Leachate pool | Y | Y | |
| 45 | Vegetation | N | I | |
| 46 | Leachate seep | Y | Y | |
| 47 | Vegetation | N | I | |
| 48 | Vegetation | N | I | |
| Autumn | | | | |
| 49 | Leachate seep | Y* | Y* | Y |
| 50 | Snow covered soil | N | N | I(seep) |
| 51 | Leachate seep | Y | I | N |
| 52 | Vegetation | I | I | N |
| 53 | Leachate seep | I* | I* | Y |
| 54 | Snow covered soil | N | N | I |
| 55 | Snow covered soil | N | N | I(seep) |
| 56 | Leachate pool | N | N | Y |
| 57 | Snow covered soil | N | N | I |
| 58 | Leachate seep | N | N | N |
| 59 | Leachate seep | N | N | Y |
| 60 | Leachate seep | N | N | N |
| 61 | Leachate seep | N | N | Y |

Y - feature identified
N - not identified
I - inconclusive or indistinct
* - liquid in perimeter ditch

No single sensor identified all of the leachate discharges, although each of the 1980 sensors defined the area of most continuous visible leachate seepage. In particular, seepage into Redhill Creek is not well detected. The thermal signature of the Creek itself obscures thermal anomalies caused by leachate discharge. With regard to photography, discharge which is occurring at stream level or as base flow is not visible and, therefore, not detectable. Interpretation of the archival photography provides general information on probable leachate discharge areas, but obviously does not identify active seepage.

## 6. CONCLUSIONS

Archival photography appears to be the most cost effective remote sensing tool for the Upper Ottawa Street landfill. When interpreted carefully, it provides an indication of seepage direction.

Recent (1980) imagery identified the major visible areas of leachate discharge. However, its application to the Upper Ottawa Street landfill appears to be restricted. The visible leachate impacts are confined to the site perimeter, and are predominantly perched leachate seepage. Leachate flowing to depth is below ground and not detectable with any remote sensing device.

## 7. IMAGERY USED AT THE UPPER OTTAWA STREET SITE

### 7.1 Archival

Archival photographs used at this site are:

| YEAR | SCALE | PHOTO NUMBER | SOURCE |
|---|---|---|---|
| 1954 | 1:15840 | 4309-27 # 12-13 | M.N.R. |
| 1965 | 1:17000 | A19358 # 42-44 | N.A.P.L. |
| 1972 | 1:15840 | 4309-1 # 148-149 | M.N.R. |
| 1978 | 1:10000 | 4314-52 # 16-17 | M.N.R. |

### 7.2 1980 Imagery

Figure F.4 shows the area covered by the 1980 imagery. Scales, date and target photographs are given for each imagery set.

### 7.3 Sources

A complete set of imagery is available for viewing at the following offices of the Ontario Ministry of the Environment:

Solid Waste Unit
Waste Management Branch
Ontario Ministry of the Environment
4375 Chesswood Drive
Downsview, Ontario
M3J 2C2

West Central Region (Hamilton Regional Office)
Ontario Ministry of the Environment
140 Centennial Parkway North
Stoney Creek, Ontario
L8E 3H2

Copies of imagery may be obtained from:

1980 imagery - Contact MOE office.

Archival:

National Air Photo Library
Energy, Mines and Resources
615 Booth Street
Ottawa, Ontario
K1A 0E9
Telephone: (613) 995-4560

Public Service Centre
Ontario Ministry of Natural Resources
Whitney Block
Queen's Park
Toronto, Ontario
M7A 1W3
Telephone: (416) 965-1123

TD
159.3
.O6
R46
1982
vol. 2

Remote sensing techniques &
waste management assessments /

76628